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BY JOHN GREGORY, ESQ., C.E.

Author of the Philosophy and Practice of Arithmetic, Practical Geometry, Conic Sections,
Mensuration, Astronomy, Use of the Globes, Construction of Maps, &c. &c.

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THIS VOLUME IS DEDICATED

AS A TESTIMONY OF RESPECT AND ESTEEM,

BY

THE AUTHOR.

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ERRATA.

VOL. I.

Page	28	Line	22	from top, for	2.68690	read	2.68610
...	36	...	7	...	35″	...	25″
...	36	...	21	...	.41072	...	.91176
...	36	...	22	...	.58928	...	.08824
...	60	...	5	...	C	...	*c*
...	61	In the figure, for *a* read *b* and *b* for *a*					
...	61	...	29	...	70°	...	71°
...	63	...	18	...	DC	...	DB
...	63	...	20	...	AB and DC	...	AC and DB
...	64	...	5	...	CD and .89013	...	BD and 90013
...	64	...	6	...	.89013	...	.90013
...	64	...	8	...	.91186	...	.92186
...	75	...	15	...	.90796	...	.47209
...	75	...	19	...	.90796	...	.47209
...	75	...	20	...	.42947	...	.86533
...	76	...	3	...	9.97159	...	10.42726
...	76	...	4	...	.54376	...	.99943
...	76	...	6	...	.50499	...	.96065
...	85	write C at top of tower, and state as follows, viz.: In triangle CDB 81.49+40=121.49, and 81.49—40=41.49; then 121.49 : 41.49 : : tan. $\frac{C+B}{2}$=69° 3′ : tan. $\frac{C-B}{2}$=42° 24′½; then to find BC 69° 30′—42° 24′½= 27° 5′½=angle C, sin. 27° 5′½ : 40 : : 41° : CB=57.62.					
...	89	in figure, write R under P.					
...	91	...	7	...	1509.7	...	1569.7
...	94	...	17	...	40°	...	41°
...	94	...	20	...	106°	...	105°
...	94	...	23	...	106° and 98262	...	105° and 98474
...	94	...	24	...	.76077	...	.76289
...	94	...	26	...	.01603	...	.01815
...	95	...	3	...	40° and .80942	...	41° and .81825
...	95	...	4	...	.58757	...	.59640
...	95	...	6	...	709.3 and .84283	...	710.7 and .85166
...	95	...	8	...	40° and 64°	...	41° and 63°
...	95	...	12	...	64°	...	63°
...	95	...	13	...	21°	...	22°
...	95	...	14	...	21° and .56407	...	22° and .58284
...	95	...	16	...	64° and .95482	...	63° and .95110
...	95	...	17	...	.55688	...	.55316
...	96	...	18	...	.56407	...	.58284
...	96	...	19	...	983.6 and .99281	...	934 and .97032
...	101	...	12	...	58′	...	50′
...	101	...	19	...	10.46	...	1.046
...	108	supply the diagram.					
...	113	...	2	...	230.94	...	2309.4
...	113	...	4	...	519.64 and 2.715703	read	5196.4 and 3.715703
...	113	...	5	...	57.76 and 1.761627	...	577.6 and 2.761627
...	113	...	8	...	2.715703	...	3.715703
...	113	...	13	...	.547689	...	.549030
...	113	...	17	...	.547689	...	.549030
...	113	...	18	...	4944 and .694021	...	4928 and .692680
...	180	...	11	...	encloser	...	enclosure
...	298	in the figure, ED should be drawn parallel to BC.					

ERRATA.

VOL. II.

Page 208. *Belfast.* There have been two reservoirs, for supplying the wealthier inhabitants with water, for a considerable time past. New waterworks are in progress of execution, for supplying the town with excellent water from the Cave Hill.

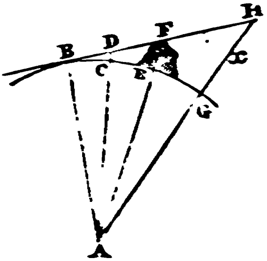
Page 209. *Dublin.* There is a second basin on the south side, which receives its water from the river Dodder, and which supplies a part of the city of Dublin with water.

THE

PRACTICE OF LEVELLING.

Levelling is a delicate and important branch of engineering. It enables us to find the exact difference of level between any number of places, and to represent the contour of any portion of the country through which it may be necessary to run a road or canal. A well connected series of levels points out the proper directions to conduct water, either for the purpose of drainage or irrigation. In conducting an extensive trigonometrical survey, the difference of level between stations is found by means of reciprocal angles of elevation and depression taken with a theodolite, which, in such operations, answers the purpose very well. In surveying, the theodolite being fixed at every station, no time is lost in preparatory adjustments to take the vertical angles, subtended by remote stations, whose distances are known by calculation. The vertical angles and distances being known, and due allowance made for the effect of the earth's convexity, and the influence of refraction, a series of levels may be taken very expeditiously, and sufficiently accurate: but for expedition and accuracy it is far inferior to the levelling instruments now in use. The theodolite, therefore, is never used for levelling purposes, except in the case of a trigonometrical survey.

To understand the principle of levelling, it may be necessary to premise, "that two or more places on the surface of the earth, equally distant from its centre, are on the same true level. Also, one place is higher than another, when it is farther from the centre of the earth, and a line equally distant from that centre in all its points, is called the line of true level. Hence, because the earth is round, that line must be a curve, and make a part of the earth's circumference, or at least parallel to it, or concentric with it, as the line BCE, which has all its points equally distant from A, the centre of the earth, considering it as a perfect globe. But the line of sight BDFH, given by the operation of levels, is a tangent, or a right line perpendicular to the semidiameter of the earth at the point of contact B, rising always higher above the true level, the farther the distance is, this being called the apparent line of level.



"Thus, CD is the height of the apparent level above the true level, at the distance of BC or BD; also EF is the excess of height at E, and GH at G. The difference, it is evident, is always equal to the excess of the secant of the arch of distance above the radius of the earth."

As the points D, F, H, are higher than the point B, though all situated in the same line of sight, it is evident that a fluid cannot rest at any of those points, but will rush towards B, where alone it will remain quiescent. It is also evident that the farther any of those points is from the point of contact B, the greater is its elevation above it; from which it appears that the curvature of the earth has the effect of depressing the apparent place of every object on its surface, and likewise that the quantity of depression has reference to the distance between the objects. To calculate the amount of depression or elevation due to the curvature of the earth, put a for the arc BG, t for the tangent BH, r for the radius of the earth, and x for the excess of AH above AG, which is the excess of the apparent above the true level. Then $(r+x)^2=r^2+t^2$; then, by squaring the left hand side of the equation, we get $r^2+2rx+x^2=r^2+t^2$, whence $x(2r+x)=t^2$. Now, as x is so small, when compared with the radius of the earth, we may substitute $2r$ for $(2r+x)$; likewise, in short distances, we may substitute the arc a for t. Hence $2rx=a^2$, and $x=\frac{a^2}{2r}$. Now if we assume the diameter of the earth at 7916 miles, we get $x=8.004$ inches for one mile, or $\frac{2}{3}$ of a foot nearly. Now, as x increases as the square of a, the correction for curvature in feet, is two-thirds of the square of the distance in miles. The last figure shows that though a great number of places be situated in the same line of sight, no two of them have the same level. The top of the mountain F, is in the same line of sight as B, but is higher than it, in point of level, by the altitude EF. Upon a knowledge of this fact, connected with the well known tendency of every fluid to descend from a higher to a lower place, when allowed to act freely, is founded the practice of conveying water from one locality to another. Let us suppose a spring to be on the side of a hill, and a town on the side of an opposite hill, with a valley between them; and that the spring seen from the town, appears, by a levelling instrument, to be on a level with one of the streets, to which it were desirable to bring the water for the use of the town. Now let us suppose the spring is one mile from the town; then from what has been proved above, we are sure the water is 8 inches above the level of the town, and therefore we conclude that the water may be conveyed through pipes across the valley from the spring to the town. A case of this kind occurs in the town of Enniscorthy, which is badly supplied with water; but might at a small expense be amply supplied from a copious spring on the opposite hill, which commands the town.

Further, let us suppose a spirit-level is planted on an eminence, by which we observe the top of a hill, distant 6 miles, just in the horizontal wire of the telescope; required the difference of level, allowing the height of the instrument to be 4½ feet.

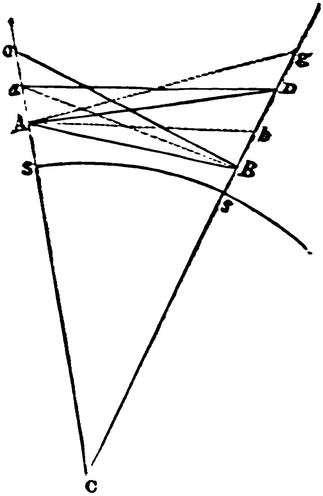
⅔ foot=curvature in one mile.
36 feet=square of the distance.
24 feet=amount of curvature in 6 miles.
4½ feet, height of instrument, to be added.

28½ feet, the difference of level.

But the effect of the earth's curvature is modified by refraction, which elevates the apparent place of every distant object. No object is seen in its true position, but is always seen in the direction of the ray of light which conveys to us the impression of it. The luminous particles, in passing through the atmosphere, which is composed of an infinite number of concentric strata, increasing in density towards the earth's surface, are refracted or bent continually towards the perpendicular; and therefore they must describe a curve in their passage, of which the last portion, or rather its tangent, indicates the apparent elevated situation of a remote object. This curve may be considered as very nearly an arc of a circle, having for its radius six times the radius of our globe. Therefore, to correct the error arising from refraction, we have only to diminish the effect of the earth's curvature, by one-sixth part; or to deduct from the vertical angles, the twelfth part of the measure of the intercepted terrestrial arc.

It must, however, be observed, that as the refraction varies with the density and temperature of the atmosphere, which are constantly changing, especially in this unsteady climate, no rule can be given for finding the exact amount of refraction, which will answer in every case. It is, however, usual to estimate the effects of refraction at some mean quantity, either in terms of the curvature, or of the arc of distance; one-seventh of the curvature is usually allowed for the correction of refraction: therefore, when we make a correction, combining curvature and refraction, the formula is correction in feet$=\frac{4}{7}$ D^2; D being the distance in miles between the place of observation and the distant object observed. From what has been said above, in reference to the variable quantity of refraction, it is not pretended that the formula here given will always produce accurate results. General Roy, aware of this fact, varied the amount of correction, assuming it at $\frac{1}{10}$, and sometimes at $\frac{1}{11}$, without, however, ascertaining these quantities from actual observation of the reciprocal angles of elevation or depression, which are necessary for the easy solution of the case, as shall be seen further on. Few persons who havec onsidered this subject, agree as to the proper allowance to be made for refraction. Dr. Maskeline makes it $\frac{1}{10}$ of the intermediate arc, Legendre $\frac{1}{14}$, Bouger $\frac{1}{9}$; General Roy has varied it from $\frac{1}{2}$ to $\frac{1}{24}$.

In the Trigonometrical Survey of England, vol. ii., the allowance is from $\frac{1}{5}$ to $\frac{1}{32}$ of the intermediate arc. This difference of allowance arises not from inaccuracy of observation, but rather from the inconstancy of the producing causes. The evaporation of rains and dews, and a change of temperature producing variable and partial refractions, the engineer or surveyor should find the exact amount from actual observations. The following method for finding the amount of refraction, is perhaps one of the best that could be employed.



Let C represent the centre of the earth, A and B the true places of two stations above the surface, which in the accompanying figure is represented by SS. AD and BO are horizontal lines at right angles to the radii AC and BC. And let *a* and *b* be the apparent places of A and B. Thus the angles DAB and OBA are called the reciprocal depressions, and their sum would always be equal to the contained arc, if there was no refraction. But as *a* and *b* are the apparent places of the objects A and B, the observed angles of depression will be DA*b* and OB*a*; therefore their sum, taken from the contained arc of distance, will leave the angles *b*AB and *a*BA, the sum of the two refractions, half of which will give the refraction. Hence the following rule, when both objects are reciprocally depressed. Deduct the sum of the two depressions from the contained arc, and half the remainder is the mean refraction. If one of the points, B, be elevated to the point *g*, instead of being depressed, then the rule is, subtract the depression from the sum of the contained arc, and the elevation and half the remainder is the mean refraction. The angles should be taken simultaneously by means of signals, or by watches previously regulated for the purpose. The amount of refraction found by the above rules must be subtracted from the angles of elevation as a correction; each of the observations must be previously reduced, when necessary, to the axis of the instrument. The following example, taken from the survey of England, will be a sufficient illustration.

At the station on Allington Knoll, which was known to be 329 feet above low water mark, the top of the staff on Tenterdon steeple was depressed by observation 3′ 51″, and the top of the staff was 3.1 feet higher than the axis of the instrument, when it was at that station. The distance between the stations was 61,777 feet, at which 3.1 feet subtend an angle of 10.″4, which being added to 3′ 51″, gives 4′ 1″.4 for the depression of the axis of the instrument, instead of the top of the staff. On Tenterdon steeple, the ground at Allington Knoll was depressed 3′ 35″: the axis of the instrument, when at this station, was 5.5 feet above the ground, which subtend an angle of 18″.4; and this deducted from 3′ 35″, leaves 3′ 16″.6 for the depression of the axis of the instrument.

Now, to convert the intercepted distances in feet to degrees, &c., we say, as the number of miles in a degree is to 60′, so is the number of feet in the contained arc to the corresponding degrees, &c. By this rule—

Contained arc 61,777 feet ... ... 10′ 6″ nearly.
Sum of depression 4′ 1″.4+3′ 16″.6 7 18

2) 2 48

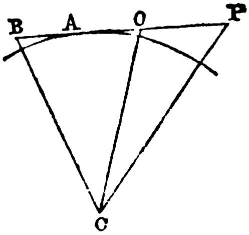
Mean refraction ... 1 24

In this example it may be observed, that the mean refraction is $\frac{1}{7}$ of the contained arc, nearly.

The depression at Allington Knoll was 3′ 16″.6, which being added to the mean refraction, gives 4′ 40″.6 for angle corrected for refraction.

Now, 4′ 40″.6 being less than half the contained arc (5′ 3″) by 22″.4, it is evident that the place of the axis of the instrument at Allington Knoll is above that at the other station by 6.7 feet, which is the amount that this angle 22.″4 subtends. Then 329 diminished by 6.7, leaves 322.3 feet for its height when on Tenterdon steeple, corrected for refraction and curvature.

In the common practice of levelling for roads or canals, neither curvature or refraction is allowed for. Because when the levelling instrument is in the middle point between both stations, they are equally affected both by curvature and refraction.



Let us suppose the stations B and O to be equally distant from the point of observation A, it is manifest they would be equally affected both by curvature and refraction, and consequently would remain equally distant from the centre; but if we suppose the instrument at A, as before, and the stations to be at unequal distances from it, as B and P, then the amount of curvature at P would be greater, which, in very delicate operations, should be allowed for, if the distance OP be considerable. The station P would likewise be differently affected by refraction; but in the common operations of levelling, the distance between the instrument and either station is in general so small, that no appreciable error can arise from the inequality of distance, being at most but a few yards. In the practice of levelling, however, it would be advisable to plant the instrument as near the middle point between the stations as you could guess. The assistant could very easily accomplish this, by pacing the distance between the back station and the instrument, and going forward an equal distance.

Hence it appears, that in the practice of levelling for roads, canals, or sections, curvature or refraction is not to be taken into account, as the work is not affected by either; but in extensive trigonometrical operations, when the stations observed might be many miles distant from the place of observation and from each other, due allowance must be made both for curvature and refraction, which, in such cases, amount to very considerable quantities. A correction must likewise be made for the effects of curvature and refraction, when only one observation is taken, in order to ascertain the relative height of a distant station as compared with the place of observation, as they are differently affected.

ON LEVELLING WITH THE THEODOLITE.

Levelling for sections is performed by the theodolite, by means of the angles of elevation and depression of any station, and its distance from the place of observation.

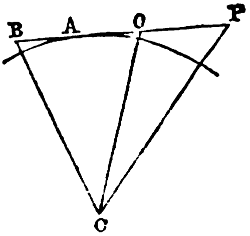
Contained arc	10′ 6″ nearly.
Sum of depressions	7 18
	2 48
Mean refraction ...	1 24

In this example it may be observed, that the mean refraction is [illegible] of the contained arc nearly.

The depression at Allington Knoll was 3′ 16″.6, which being added to the mean refraction, gives 4′ 40″.6 for angle corrected for refraction.

Now, 4′ 40″.6 being less than half the contained arc (5′ 3″) by 22″.4, it is evident that the place of the axis of the instrument at Allington Knoll is above that at the other station by 6.7 feet, which is the amount that this angle 22.″4 subtends. Then 329 diminished by 6.7, leaves 322.3 feet for its height when on Tenterdon steeple, corrected for refraction and curvature.

In the common practice of levelling for roads or canals, neither curvature or refraction is allowed for. Because when the levelling instrument is in the middle point between both stations, they are equally affected both by curvature and refraction.



Let us suppose the stations B and O to be equally distant from the point of observation A, it is manifest they would be equally affected both by curvature and refraction, and consequently would remain equally distant from the centre; but if we suppose the instrument at A, as before, and the stations to be at unequal distances from it, as B and P, then the amount of curvature at P would be

greater, which [illegible]
allowed for, if the dist[illegible]
station P would [illegible]
fraction; but in the com[illegible]
distance between [illegible]
in general so small [illegible]
from the inequ[illegible]
yards. In the prac[illegible] it
be advisable to ma[illegible]
point between the st[illegible]
assistant could [illegible]
the distance between [illegible]
and going between [illegible]

Hence it appear[illegible]
for roads, cana[illegible]
not to be taken [illegible]
by either; [illegible]
when the sta[illegible]
from the place [illegible]
allowance [illegible]
fraction, wh[illegible]
siderable qua[illegible]
made for the [illegible]
only one obs[illegible]
the relative [illegible]
with the pla[illegible]
affected.

ON LE[illegible]

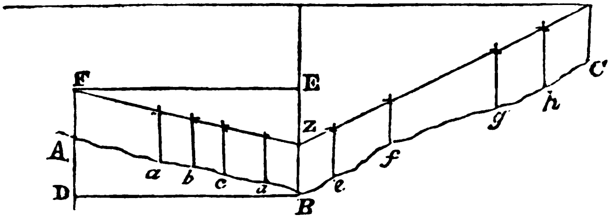
Levell[illegible]
by means [illegible]
any station [illegible]

After the line to be levelled has been marked out by long pickets, placed at every change of inclination of the surface, you procure a levelling staff, and set the vane or some visible mark to the exact height of the optical axis of the telescope. Now the theodolite being fixed at the extremity of the line, and the assistant sent to the first of these marks in the line, the angle of elevation or depression, which the mark on the levelling staff makes, is read off on the vertical arc of the theodolite, and the distance between the instrument and the staff measured. If the vane or mark on the staff is intended to be permanent, the instrument must be set to one fixed height, by means of a rod marked for the purpose. When the height of the instrument is altered, the vane or mark on the staff must be changed, so as always to be of the same height from the ground as the optical axis of the telescope. It is sometimes the practice, in order to insure greater accuracy, to make reciprocal observations, by making the instrument and staff change places.

It matters not whether the distances are chained before or after the angles are observed, provided marks are left at every change in the surface to be levelled. Both operations may be performed at the same time, by first fixing the instrument at the extremity of the line, and raising or lowering the vane, till it is bisected by the horizontal wire of the telescope, taking care to note the height on the staff at each place.

When the instrument and staff change places, for the purpose of comparing the angles of elevation and depression, if there is any difference a mean is taken, to which the instrument must be set, and clamped. In planting the staff, the assistant is only to fix it on those points where the general inclination of the line changes, and there take the angles of elevation or depression as the case may require, not regarding all the trifling undulations on the surface between the principal points of deflexion. When the distance between these points is considerable, a correction must be made for curvature and refraction.

In the annexed sketch, the instrument is placed at A, and the staff at B, marked at the height of the instrument: between these points, the levelling staff is set at *a*, *b*, *c*, *d*, which are pointed out by the small undulations of the surface. The angle of depression to B is taken, and if great accuracy be required, the angle of elevation at B to A is observed; then a mean of both these angles of depression and elevation is taken, and the vertical arc being clamped to this mean angle, the telescope is again made to bisect the vane at B. Measure the distances A*a*, &c., and note the height of the vane at *a*, *b*, *c*, *d*; then bring the instrument to B, and take the angle of elevation to C; and note the height of the vane at the intermediate points *e*, *f*, *g*, *h*; and measure the distances B*c*, &c. as before. Now, having the angle of depression at F, and the distance AB (=FZ), the height EZ (=AD) may be found by the following rule:—As radius is the distance AB (=FZ), so is the sine of the angle of depression at F to the height EZ (=AD). A similar process



will find the height of the point C. Let us suppose the angle of depression at F to be 3° 20′, and when the instrument and staff change places, the angle is found to be 3° 22′; the mean of which, with the former, is 3° 21′; the distance AB being measured, was found to be 22 chains; required the height AD; or in other words, the height of the point A above B.

Rad. 90	10.00000
FZ (=AB) 2200 ...	3.34242
Sin. ∠ F 3° 21′ ...	8.76667
	12.10909
	10.00000
EZ (=AD,) 128.5 ...	2.10909

This shews that the difference of level between the points A and B is 128.5 links, which, by reduction, is equal to 84.81 feet. No allowance has been made here for curvature or refraction, which amount to .04 foot. Then 84.81+.04=84.85 feet, the height of the point A above B. By a similar process, the difference of level between B and C may be found.

The work may be represented on paper, by drawing a horizontal line, and protracting the angles of depression or elevation, and laying off the distances on the hypothenuse. The respective heights of the vane being laid off from these points in a vertical direction, will give the points *a*, *b*, *c*, *d*, &c., which mark out the undulation of the ground. Instead of measuring the distances by the chain, they may be ascertained with sufficient accuracy by means of a micrometer attached to the eye-piece of the telescope. The field-book, in this species of levelling, is very easily kept, nothing more being required than to register the vertical angles and distances in two separate columns, and the correction for curvature and refraction in a third.

Levelling may be performed by the theodolite on the same principle as by the spirit-level. The instrument is first levelled, and the vertical arc set to zero; then the telescope is directed to a staff placed at the back station, and after having registered the height of the vane, the telescope is directed to a staff placed at the forward station, and the height registered in its proper column, as before; then the distance between both stations is measured and noted down.

The use of the theodolite, as a levelling instrument, cannot be recommended, except in trigonometrical surveys. It might be used with some advantage when a number of cross sections is required, as these may be observed without changing the instrument.

The theodolite may be employed with advantage in taking trial sections for a railroad, but is far inferior to a French instrument very generally used for that purpose. This instrument shall be described farther on.

It has been stated before, that in the real practice of levelling, the operation is not affected by curvature or refraction; the back and fore sights taken with the spirit-level being equally affected. But when only a single altitude is taken, and the station observed is at a considerable distance, then reference may be had to the following tables, which contain the correction for curvature and refraction, for distances in chains, feet, and miles.

The tables are calculated by one of the formulas given in the preceding part of this chapter.

Of the difference of the apparent and true level for distances in feet.			
CORRECTION IN DECIMALS OF FEET.			
Distance in feet.	*For Curvature.*	*For Refraction.*	*For Curvature and Refraction.*
100	.00024	.00004	.00020
150	.00054	.00008	.00046
200	.00096	.00013	.00083
250	.00149	.00021	.00128
300	.00215	.00031	.00184
350	.00293	.00042	.00251
400	.00383	.00055	.00328
450	.00484	.00069	.00415
500	.00598	.00085	.00513
550	.00724	.00103	.00621
600	.00861	.00123	.00738
650	.01010	.00144	.00866
700	.01172	.00167	.01005
750	.01345	.00192	.01153
800	.01531	.00219	.01312
850	.01728	.00247	.01481
900	.01938	.00277	.01661
950	.02159	.00308	.01851
1000	.02392	.00333	.02059
1050	.02533	.00377	.02261
1100	.02895	.00414	.02481
1150	.03164	.00452	.02712
1200	.03445	.00492	.02953
1250	.03738	.00534	.03204
1300	.04043	.00578	.03465
1350	.04361	.00623	.03738
1400	.04689	.00670	.04019
1450	.05030	.00719	.04311
1500	.05383	.00769	.04614
1550	.05748	.00821	.04927
1600	.06125	.00875	.05250
1650	.06514	.00931	.05583
1700	.06914	.00988	.05926
1750	.07327	.01047	.06280
1800	.07752	.01107	.06645
1850	.08188	.01127	.07161
1900	.08637	.01234	.07403
1950	.09098	.01300	.07798
2000	.09570	.01367	.08003

Of the difference of the apparent and true level for distances in chains and links.			
CORRECTION IN DECIMALS OF FEET.			
Distance in Chains and Links.	*For Curvature.*	*For Refraction.*	*For Curvature and Refraction.*
100	.00010	.00001	.00009
150	.00024	.00003	.00021
200	.00042	.00006	.00036
250	.00065	.00009	.00056
300	.00094	.00013	.00081
350	.00128	.00018	.00110
400	.00167	.00024	.00143
450	.00211	.00030	.00181
500	.00261	.00037	.00224
550	.00315	.00045	.00270
600	.00375	.00054	.00321
650	.00440	.00063	.00377
700	.00511	.00073	.00438
750	.00586	.00084	.00502
800	.00667	.00095	.00572
850	.00753	.00108	.00645
900	.00844	.00121	.00723
950	.00940	.00134	.00806
1000	.01042	.00149	.00893
1050	.01149	.00164	.00985
1100	.01261	.00180	.01081
1150	.01378	.00197	.01181
1200	.01501	.00214	.01287
1250	.01628	.00233	.01395
1300	.01761	.00252	.01509
1350	.01899	.00271	.01628
1400	.02043	.00292	.01751
1450	.02191	.09313	.01878
1500	.02345	.00335	.02010
1550	.02504	.00358	.02146
1600	.02668	.00381	.02287
1650	.02837	.00405	.02432
1700	.93012	.00430	.02582
1750	.03192	.00456	.02736
1800	.03377	.00482	.02895
1850	.03567	.00509	.03058
1900	.03762	.00537	.03225
1950	.03963	.00566	.03397
2000	.04169	.00596	.03573

Of the difference of the apparent and true level for distances in miles.			
CORRECTION IN DECIMALS OF FEET.			
Distance in Miles.	*For Curvature.*	*For Refraction.*	*For Curvature and Refraction.*
¼	.0417	.0060	.0357
½	.1668	.0238	.1430
¾	.3752	.0536	.3216
1	.6670	.0953	.5717
1½	1.501	.2144	1.286
2	2.668	.3811	2.287
2½	4.169	.5955	3.573
3	6.003	.8561	5.147
3½	8.171	1.167	7.003
4	10.672	1.525	9.147
4½	13.547	1.929	11.577
5	16.675	2.382	14.293
5½	20.177	2.882	17.294
6	24.012	3.430	20.582
6½	28.181	4.026	24.155
7	32.683	4.669	28.014
7½	37.519	5.360	32.159
8	42.688	6.100	36.588
8½	48.191	6.884	41.307
9	54.027	7.718	46.309
9½	60.197	8.600	51.597
10	66.700	9.529	57.171
11	80.707	11.530	69.177
12	96.048	13.721	82.327
13	112.723	16.103	96.620
14	130.732	18.676	112.056
15	150.075	21.439	128.636
16	170.752	24.393	146.359
17	192.763	27.538	165.225
18	216.109	30.873	185.236
19	240.787	34.398	206.389
20	266.810	38.114	228.686

Description of various levelling instruments in common use, with instructions to adjust them.

The Y Level.—This instrument has its name from the resemblance its supports bear to the letter Y. It is not very generally used at present, its place being supplied by others of more delicate and accurate construction. It has, however, one great advantage to recommend it, namely, the facility of adjusting all its parts; and it is on account of this quality of the instrument, no doubt, that old practitioners continue still to use it, notwithstanding its manifest inferiority of construction, as compared with others which shall be presently noticed. The first adjustment in this levelling instrument is the line of callimation. This adjustment is performed exactly like that of the telescope in the theodolite. You open the rings that confine the telescope, adjust it for perfect vision, that is, adjust it so that the cross-wires and the object to be observed may be seen with perfect clearness and distinctness. Direct the telescope to some well defined object, paying no regard to the spirit-bubble, which object bisect with the cross-wires, and then clamping the instrument firm, turn the telescope round very gently in the Y's, and if the bisection continue during an entire revolution, the line of callimation is properly adjusted. But should not the cross-wires continue to bisect the object observed during an entire revolution of the telescope in its Y's, then an error exists, which must be corrected by means of the screws which carry the cross-wires or diaphragm. When the bisection continues perfect during an entire revolution of the telescope in the Y's, which support it, then you may conclude that all is right.

Having adjusted the line of collimation, level the instrument perfectly, by means of the parallel plate-screws; then reverse the telescope, and if the bubble return to the middle of the tube, all is right; but if it should not return, observe the end it approaches, then lower that end half the amount of the error, by means of the screws which connect it with the telescope, and correct the other half by means of the parallel plate-screws. Again, reverse the telescope, and observe whether the spirit-bubble returns to the middle of the tube, if it should not, the correction must be repeated in the same manner as before directed. You may not perhaps succeed in the perfect adjustment of the spirit-bubble till after three or four trials, but a little practice will soon enable you to adjust this part of the instrument with ease and expedition.

The next adjustment is to make the instrument revolve on its stand—the bubble remaining in the middle all the while. When the instrument, by turning it all round, does not retain the bubble in the centre of the tube, raise or lower the milled-head screw, which carries one of the Y's, one half the observed error, and correct the other half by means of the parallel plate-screws. Again, revolve the instrument on its stand, and if the bubble be observed to recede from the centre, the correction must be repeated. The surveyor or engineer should be particular in examining the adjustment of the several parts of this instrument every morning before commencing operations. By paying due attention to this most essential part of his duty, errors will be prevented and correctness ensured, so far as the duty of the instrument is concerned.

In describing the method of adjusting the theodolite, it was particularly recommended to attend, in the first instance, to the eye-piece of the telescope. This is one of the first adjustments to be attended to in the levelling instrument. The eye-piece is to be drawn out till the cross-wires are rendered perfectly distinct, and the instrument is free from parallax, than which nothing could be more perplexing. Its presence is known by fixing the intersection of the cross-wires on some distant object, and a displacement of the contact taking place on moving the eye up or down, or from the right to the left, or the contrary. Having adjusted the eye-piece, the next thing to be attended to is the adjustment of the object-glass, which is very easily accomplished by means of a screw that gives it motion.

TROUGHTON'S IMPROVED LEVEL.

In this levelling instrument, the spirit-level is fixed to the telescope, and consequently it has no separate means of adjustment. The telescope is also firmly fixed in a sort of frame, and therefore it cannot be reversed. Hence, the adjustment of the line of collimation must depend on the spirit-level. To adjust the instrument, you first adjust the level by correcting half the error when turned round, by means of the screws acting on the supports, and the other half by the plate-screws; then the line of collimation is made to agree with the corrected level in the following manner:

Set up a staff at the distance of about two or three hundred yards, and note the height of the intersection of the cross-wires on it; then let the instrument and staff change places, observe the height, as before, and if the difference of level remains unaltered, the line of collimation, or optical axis of the telescope, is correct; if not, apply half the difference of the results to the observed height of the vane on the staff, and adjust the cross-wires to this height, by means of the screws which give motion to the diaphragm.

There is a practical difficulty in finding the exact difference of level between the place of the instrument and that of the staff, by merely causing the instrument and staff to change places. This difficulty may be obviated in the following manner: Choose a level piece of ground, upon which set up your instrument, and level it by means of the parallel plate-screws; then on either side of it drive stakes into the ground, upon which place the staff alternately, and upon it read off the height of the intersection of the cross-hairs of the telescope: the difference of these two readings on the staff will be the true difference of level between the stakes, notwithstanding the error at the same time existing in the instrument. Now remove your instrument a few feet beyond one of the stakes, and note the reading on the staff placed alternately on the stakes, and if both readings give the same difference of level as before, the optical axis of the telescope is right; if not, alter the position of the diaphragm by means of its screws, until the reading on the farther staff gives the exact difference of level obtained when the instrument occupied the point equally distant from the stakes. A small change in the position of the diaphragm will not much affect the reading on the nearer staff. Now turn the instrument round on the staff-head; and observe if the bubble retains its position in the tube, if it does, all is right; if not, lower the end to which the bubble approaches, as was taught in the adjustment of the Y level; thus correcting half the error by means of the capstan-headed screws attached to the end of the horizontal bar, and the other half by the parallel plate-screws. After every correction, the instrument must be tried, and if any error be found to exist, the process of correction must be repeated.

Description, use, and adjustments of Gravett's Level, commonly called the Dumpy Level.

Mr. Gravett, an English engineer of considerable eminence, invented some few years ago a levelling instrument, which is by far the most perfect for levelling operations.

The only disadvantage attending it, is the great difficulty in adjusting its several parts. This is doubtless a great objection to its general use, especially among unscientific engineers, unacquainted with the general principles of practical science.

This difficulty of adjustment is, however, more than counterbalanced by the many advantages peculiar to it. By it we are enabled to read the divisions on the staff, distinctly, at any distance within the probable range of practice; thus avoiding the tedious and disagreeable practice of communicating intelligence to the assistant by signs, and also guarding against the errors consequent on his neglect or ignorance. The object-glass in the levelling instruments already described not being sufficiently ample, the field of view is necessarily limited; besides, their telescopes are not sufficiently brilliant to enable the engineer to read the small divisions on the staff, and thereby obviate the inconvenience and defect above alluded to. Their great length, as compared with Mr. Gravett's instrument, renders them less portable, and much more liable to accidents; and though they are more easily adjusted, they are much more easily deranged.

All these objectionable defects are obviated in this new instrument, which has deservedly become a general favourite among engineers. Its object-glass is large, and therefore affords a spacious field of view. It inverts objects, and renders the smallest divisions on the staff sufficiently distinct to be read at a moderate distance. Every distinct part of it has a distinct means of adjustment. It is therefore, with a single exception, (the difficulty of adjustment,) the most perfect instrument now in use. The adjustments of this level, as described by the inventor, may be found in Mr. Simms' treatise on mathematical instruments—a little work of superior merit, containing more information on the different subjects it treats, than any other treatise the author has seen.

Among the advantages to be noticed, as peculiar to Mr. Gravett's levelling instrument, are a cross level, placed at right angles to the principal one, which considerably facilitates all the preparatory steps for observation, preventing the necessity of turning the instrument from side to side, during the time it is being levelled; and a reflecting mirror, capable of being placed on the principal level-tube, for the purpose of shewing if the instrument deviates from its horizontal position while the observer is noting the observation, the mirror being previously adjusted.

FRENCH REFLECTING LEVEL.

This little instrument consists of a small bit of looking-glass, set in a vertical metal plate, weighing about 1℔, or perhaps much less. Its verticality is insured by its being suspended from a ring, which allows it to hang freely, but not turn round its axis of suspension. When the mirror is vertical, and held at an arm's length at the height of the eye, the image and eye are evidently in the same horizontal line; and any distant object coinciding with these must necessarily be on the same level. Hence it appears that this little portable instrument is very valuable in seeking the best direction to carry a road or canal through any portion of a country; as the relative heights of distant points are at once ascertained by merely turning round, holding the instrument at the same height all the while.

Its value, however, consists only in its portability and expedition in comparing heights, with a view to strike out the best route for roads, canals, or other water-courses. The person using it must ascertain the height of his eye, which is a constant quantity. It answers very well for military purposes, but is by no means adapted to levelling operations requiring minute details. This instrument is adjusted by planting a levelling-staff at a small distance behind the mirror, giving directions to raise or lower the vane, so as to make it to coincide with the line of sight: reverse the mirror, and let the vane on the staff be again made to coincide with the line of sight, the staff remaining stationary; take a mean between these two heights, and adjust the mirror to this mean height, by means of a small screw attached to the instrument.

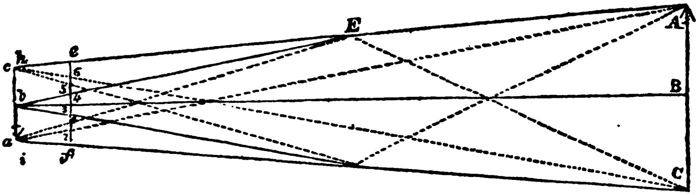
There are other levels used by civil and military engineers, artificers, &c.; such as the French water-level, much used on the Continent; the mason's level, the road maker's level, not unlike the last; and several others, too imperfect and limited in their use to deserve any notice in this place. Their use and application will at once be understood, from what has been said of the more perfect instruments already described.

ON INSTRUMENTAL PARALLAX.

Instrumental parallax is often a source of much error in surveying and levelling operations. Its cause is not difficult to be understood. Modern theory teaches us to believe that light consists in the vibration of an elastic fluid. Be this as it may, we are sure that the rays of light are the media through which the representation of an object is conveyed. We are also aware, from actual experiment, that when these rays impinge upon media of different densities, they become refracted or bent, which necessarily causes a convergence towards a particular point, called the focus.

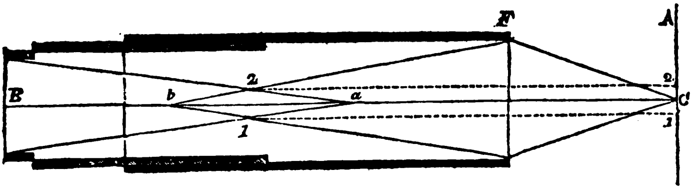
This focus is situated in an imaginary plane, on which the picture of the object is supposed to be delineated. Now if this plane, containing the picture of the object, be not placed exactly in the focus, the points of the object become undefined in consequence, and this consequence we call parallax. This parallax is great or small, according to the distance the imaginary plane is from the focus.

Let A B C represent an object, and *abc* its corresponding



points on the plane *hi*, upon which every point of the object, after passing through the lens E, is perfectly defined: but if we suppose a plane to be situated at *ef*, the points *abc* become indefinite, and their position varies between the spaces (1, 2,) (3, 4,) (5, 6,) when the eye is turned all round when looking through the telescope.

The figure here represents the telescope of a level:



it has two lenses; the one at B is called the eye-glass, and the one at F the object-glass.

If we view the staff A, or a point C in it, we shall find the situation of the point to vary with every change of view. The amount of variation will be denoted by a space limited by the figures 1, 2, which is the extent of the parallax. Besides this variation in the apparent place of the point C, it will appear dim and ill defined. From what has been said, it is evident, that in order to obtain a clear and distinct representation of the object viewed, the eye and object-glasses must be slidden in and out till the points *a* and *b* are made to coincide; these points are called the foci of the telescope.

LEVELLING STAVES.

One of the oldest description of staves for levelling operations is that with a sliding vane, which is moved up and down by means of a chord passing through two pulleys, the one placed at the top of the staff, and the other at the bottom. This staff is sometimes graduated into feet and inches, and sometimes into feet and decimals of a foot. Its length is generally 12 feet. This staff sometimes consists of two or three sliding pieces, graduated on the face similar to the last. The vane is moved by the hand over the first piece: when the observation requires that the vane should be higher than the first division, put it to the top of this by the hand, and then slide this division up on the second division till it shall arive at 10 feet; and should not this reach to the required height, move up the second slide on the third, till the required height be attained by the vane. This staff is read by means of an index on the side. If it happens to go so high as the top of the first division of the staff, it will be 5 feet, to which is added the reading on the second division raised. Thus if the second slide be raised 3 feet 4 inches, then the reading will be 8 feet 4 inches. If the operation required the vane to be raised higher than the sum of the heights of two slides, namely 10 feet, proceed as before by moving another division, adding the reading on this to 10 feet. This staff, though subject to error, and very difficult to manage in wet weather, is the best that could be used in connection with the old spirit-level.

It is but very rarely employed at present, except among some old practitioners, who still cling to what they have been so long accustomed to. The staves now, very deservedly, in general use, are those invented by Mr. Gravett. They are graduated into feet, tenths, and hundredths; and can be read distinctly at any distance not exceeding ten or eleven chains. As the subdivisions on the staff can be read distinctly by the observer, it requires no vane, and therefore the assistant has no duty to perform, except to hold the staff in an upright position. Mr. Gravett's staves consist of three pieces, with joints similar to a fishing-rod.

Mr. Sopwith has adopted Mr. Gravett's graduation, but applied a different mechanical arrangement, by which the pieces of which his staves are composed, draw out like a telescope, a spring catch retaining each joint in its place.

Mr. Brough has contrived a form of staff, on which the figures are inverted; it is 15 feet long; but when closed, measures only 5 feet; it is shod with iron, which is, no doubt, an improvement of no inconsiderable importance. The principal objections to the use of these staves, are the difficulty of pulling out the different slides of which they are composed, in damp weather, and the weakness of the upper joints. Want of sufficient strength in the upper joints, renders them very unsteady, and therefore difficult to be observed, even in very moderate breezes. This led the author to contrive a levelling staff, obviating the objections here pointed out. It consists of two pieces, which are joined together by a peculiar sort of hinge, not very unlike a carpenter's rule. When closed, the graduated face is concealed, and therefore protected from injury or accident incidental to coach travelling. When unfolded, its face presents one uniform surface throughout, which makes it as easy to read the smallest subdivision at the bending joint as at any other part of the staff, which is not the case when the graduated face is not in the same plane. As one part does not slide in a groove within another, like those above described, it is of uniform strength, capable of resisting the pressure of the atmosphere in tolerably moderate weather, and free from the oscillating motion resulting from the weakness of the upper pieces, which must necessarily be very thin, so as to fit within the lower ones, in order to render them portable, which no doubt, the inventors had in view in their peculiar construction.

Unlike those, the author's staff is not affected by damp weather or dust, which renders it difficult to move the inner pieces up and down the grooves in which they fit. His is unfolded for use and closed for carriage in an instant, by merely touching a single bolt. The assistant holds it upright by means of a plumb, which is inserted in its side. It turns round freely upon an iron plate attached to its lower end, by which the error very often committed by the assistant, in turning the graduated face from the last forward station to become the next back-one, is prevented. Without such a plate the most careful and experienced assistant might be liable to commit an error of small amount, especially in wet weather and soft soil, into which the staff might be apt to sink after having been reversed: or in lifting it up, a clod might adhere to its lower end, that would be apt to be a source of error in reversing it. In putting down the staff, it should be pressed against the ground, so that the spot should not yield on turning it round.

Much praise is due to Mr. Gravett for his improvement, not only in the levelling-staff, but also in the levelling instrument which is called after him.

Those gentlemen who have made further improvements in the staff, deserve the thanks of the profession. The improved telescope attached to Mr. Gravett's levelling instrument, and the peculiar graduation of the staff which is used in connection with it, enables the observer to read, and note down in his field-book, the several observed heights, by which accuracy is insured, and much time saved. The improved telescope inverts the figures on the staff, which led Mr. Brough to contrive one with the figures turned upside down, so as that when viewed through the telescope they may appear upright.

This is, however, a matter of little consequence, as after a little practice, the figures can be as easily read in one position as another. Care must be taken not to mistake the figure 6 for 9, one answering for the other when inverted. This is a mistake which cannot be committed in using the author's staff, as the figure 6 is exactly at the hinge, by which it is distinguished from the figure 9.

ON LEVELLING OPERATIONS IN THE FIELD.

It will appear, at once, that to obtain the difference of level between any number of places, and from thence to delineate the contour of the surface, some reference must be made to a point from which to commence the operation. In maritime countries the several heights are counted from a point which has reference to the surface of the sea; but in situations very remote from the sea, some visible permanent mark is assumed at either end of the line, from which the several heights along the undulating surface of the ground are reckoned. A line drawn from this point, or from a point below it, called the datum line, is that upon which the several levels are based, and by means of which the section of the line is drawn. The direction of this is parallel to the horizon. The point through which the datum line is drawn, has been differently assumed by different engineers; some making it to coincide with high-water mark, spring-tides; while others assume for its position low-water mark, spring-tides. The late Mr. Nimo, whose friendship the author long enjoyed, assumed high-water, ordinary spring-tides, as his datum line, in laying down the Dublin and Kingstown Railway. When a section of a line is represented on paper, particular care must be taken to note the point or datum line from which the levels were reckoned, that reference may be made to it whenever a case, making such reference necessary, may arise.

This indeed is a legislative enactment, the necessity of which was forcibly exemplified in the memorable action brought against the Dublin and Kingstown Railway Company, by certain land owners along the line, for damages sustained by them from the overflowing of the river Dodder, which was alleged to arise from an alteration in the construction of the line and bridge; lowering the carriage-way many feet below the level shown in the original section deposited in the Clerk of the Crown's office, and thereby diminishing the waterway under the bridge. The case in dispute, (in which the author was employed, on the part of the Hon. Sydney Herbert,) could not have been well decided without a fixed datum line, which in this case passed through high-water mark, ordinary spring-tides, as shown in the original section.

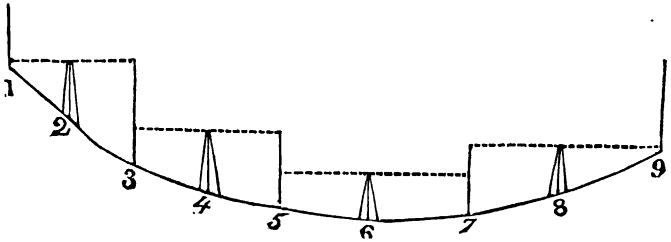
In assuming a datum line, its position might be taken below the lowest point on the line. This may be effected by ascertaining how many feet below the commencement of the line, the lowest point in it is; then assuming any number greater than this for the distance of the datum line below the commencing point, will leave the contour of the surface wholly above the datum line; which we should always recommend.

As we are upon this subject, it may be well to mention, that the high water-line is far from being fixed or permanent, even in the same locality, owing to the variety of local and inconstant causes which conspire to raise or depress it above or below the exact point prescribed by the abiding governing laws of matter. This remark applies in a special manner to the tides in rivers, channels, bays, and estuaries, which rise at different times to different heights, just according to the particular cause then operating. With respect to the low-water line, it is found sometimes to be above the natural surface of the ocean. This may occur in narrow channels, or in rivers at some distance from their mouths. This fact makes it difficult to fix the position of low-water mark. In the more open parts of the coast, the lines of high and low water are more steadily fixed, than in rivers, narrow channels, or estuaries; therefore the levels taken from the datum line, assumed at the high or low-water marks, in open coasts, do not always correspond with those taken from similar lines, in places where the water is confined, and thereby interrupted in its course. The low-water line is, however, more permanently fixed than the high-water line, and is on that account oftener assumed as a datum line. By this assumption, your section seldom runs below your datum line, which is an advantage not always gained when the high-water mark is assumed. Whether you take high or low water for your datum line, be sure to leave some permanent bench-mark at the exact height of your datum line, which will be necessary perhaps for future reference.

Having explained the instruments employed in levelling operations, we shall next give an example to illustrate their use.

Let it be required to find the difference of level between the points 1 and 9.

Set up the spirit-level at 2, and the staff at 1; level the instrument in the manner before described, and



direct the telescope to the staff at 1, looking along the line of sight represented by the dotted line; read the division on the staff, which is rendered sufficiently distinct by the improved telescope, and write the height thus read off in a column, headed B. Sights. This height we shall suppose to be 4. 8. 6 feet, which may be written 4.86. Next the spirit-level is turned round towards the staff, removed from 1 to 3, and looking along the line of sight represented by the dotted line, you intersect the staff, which you read off, as before, and write the division thus read off in a second column, headed, F. Sights. The height shewn on this staff we shall suppose to be 6. 5. 7 feet, which may be written 6.57. The difference between the points at 1 and 3 is evidently 1.71 feet, which shews that there is a fall from 1 to 3, of 1.71 feet. Hence it appears that when the fore sight exceeds the back sight, there is a fall, so far, in the direction you are going. You now remove the spirit-level from 2 to 4, the assistant remaining at 3, who turns the face of the staff round towards 4, without moving it off the ground. At 4 you set up the instrument, which you level as before, and directing it along the line of sight towards 3, you intersect the staff, and note the reading in the column headed 'B. Sights.' Let us suppose this reading to be 2.76 feet; then turning the telescope about, you intersect the staff removed from 3 to 5, and note the reading thereon, in the column headed 'F. Sights.' Let us suppose this reading to be 8.79 feet: then the difference between the points 3 and 5 is 6.03 feet fall, which added to the preceding fall of 1.71, gives a fall of 7.74 feet from 1 to 5. Remove the instrument to 6, set it truly horizontal, as before, and direct it alternately to 5 and 7, where the staff is held by the assistant. Let the reading at the former point be 5.61 feet, and at the latter 8.72 feet, which gives a further fall of 3.11 feet from the points 5 to 7, which being added to the preceding fall of 7.74 feet, gives a fall of 10.85 feet, from 1 to 7. Again, remove the instrument to 8, and direct it to the staff placed alternately at 7 and 9, and register the reading in the proper columns. Let us suppose the former reading to be 6.13 feet, and the latter 3.07 feet. Here the difference is 3.06 feet, which is the rise from 7 to 9. Hence it appears that when the reading of the back sight exceeds that of the fore sight, there is a rise. It has been shewn that there is a fall of 10.85 feet from 1 to 7, and a rise of 3.06 feet from 7 to 9; then it is self evident that the difference, 7.79 feet, shews the amount of fall from 1 to 9; which may be otherwise found, by adding all the back sights together, as also the fore sights, and finding the difference of these sums, which will always give the difference of level between the extreme points, thus:

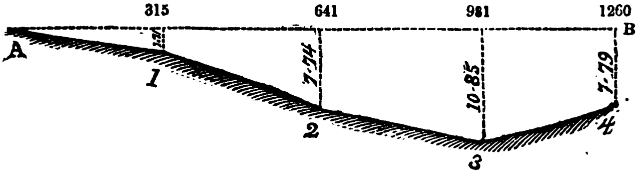
B. Sights.	F. Sights.
4.86	6.57
2.76	8.79
5.61	8.72
6.13	3.07
19.36 sum	27.15 sum
	19.36
	7.79 feet.

Here the sum of the back sights is 19.36 feet, while the sum of the fore sights amounts to 27.15 feet, which shews that the point 9 is 7.79 feet below the point 1. When it is only required to ascertain the difference of level between two distant points, the last process will be sufficient; but when a section of the line is required, the distances between the points at which the staff was placed each time, must be measured by the chain, and regularly registered, as in the following form of field-book, in which all the distances, reckoned from the point 1, are written, as may be seen in the sixth column, headed 'Distances.'

B.Sight.	F.Sight.	Rise.	Fall.	Red.lev.	Dist.	Remarks.
				o		
4.86	6.57		1.71	1.71	315	Here the datum-line is supposed to pass through the point 1, at the commencement of the line.
2.76	8.79		6.03	7.74	641	
5.61	8.72		3.11	10.85	981	
6.13	3.07	3.06		7.79	1260	
19.36	27.15					
	19.36					
	7.79					

A good method of proving the arithmetical calculations presents itself here. The difference between the sums of the back and fore sights must be equal to the last reduced level, if the work be right. In the foregoing example, the difference between the sums of the back and fore sights is 7.79 feet, which is equal to the last reduced level.

Having the field-work done, and registered in the field-book, the next thing to be done is to draw a section



of the line levelled; to do which, draw a line AB, passing through the point A, at the commencement of the line, as your datum line. Upon it mark off the distances from the point A, as 315, 641, 981, and 1260 links, by means of a graduated scale, allowing any convenient number of chains to the inch. In the present section, 4 chains (400 links) are allowed to one inch of the scale. Then by means of another scale, similar to that employed to lay down off-sets in surveying, set off the several numbers found in the column headed 'reduced level,' perpendicular to the datum line AB. This is done very expeditiously by moving the small vertical scale along the datum line, which is occupied by the horizontal scale, and setting off the reduced levels upon it.

In the last diagram, the distance-scale occupies the place AB, zero being on the point A; then on the graduated edge are marked the distances 315, 641, 981, and 1260. The small vertical scale is then applied to these points, and the numbers 1.71, 7.74, 10.85, and 7.79 are set off on it. Then the line joining the point A, and the extremities of the several ordinates 1, 2, 3, 4, will represent the surface of the line which has been levelled.

In this sketch, the vertical lines are laid down to a scale of 20 feet to one inch. Here it is necessary to observe, that in plotting a section for any purpose requiring long horizontal distances, the vertical lines must be considerably exaggerated. Were we to plot a section, allowing only the same scale for the horizontal and vertical distances, the most considerable and abrupt undulations of the surface would scarcely be perceptible. Hence the absolute necessity of increasing the vertical distances in a section far beyond their due proportion, as compared with the horizontal distances.

In keeping the field-book, the respective distances between the staves may be written in the column of distances, by which errors of calculation would be avoided, and the trouble of adding up the continuous distances from the starting point, saved.

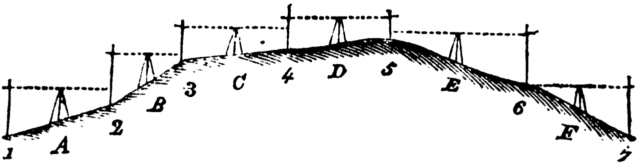
The fewer calculations you have to perform abroad the better, as the office is the best place for that work.

In fixing the instrument, it is not at all necessary to place it in a straight line between the staves; it should, however, be placed at distances from them not very unequal, in order to prevent unequal effects of curvature and refraction. The instrument is very frequently placed far out of the straight line, joining the points at which the staff is planted; this is done in order to command a proper view of the staff when placed alternately at these points.

A second staff should never be used in levelling, as the smallest difference in the graduation would ultimately cause a considerable error in the work. In measuring the respective distances between the points at which the staff is alternately placed, care must be taken to note in the field-book only the true horizontal distances, making proper allowance for the slopes of the surface, as was shewn in the practice of surveying.

When the spirit-level is out of adjustment, it often happens that after having levelled it for the back station, the bubble retires from the centre of the tube, when you turn it towards the forward station: when this happens, do not level it for the forward station again, as is sometimes the practice, but observe with it just as it stands; as the error arising from untrue horizontality will be the same in the back and fore stations, and will therefore neutralize each other. The best way, however, would be to adjust the instrument whenever it requires it.

As a further illustration of the practice of levelling, let it be required to ascertain the difference of level

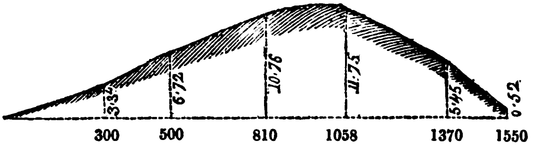


between the points 1 and 7, and also the contour of the connecting line, when properly plotted.

You place the instrument at A, and having levelled it, direct it to the staff at 1, and having registered the reading in the field-book, turn the instrument round to the staff at 2, and register the reading there; then measure the true horizontal distance between 1 and 2, and write it in its proper column. Next, remove the instrument to B, and after having levelled it, ascertain the heights cut on the staff (by the cross-wire in the telescope), when alternately placed at 2 and 3; and measuring the horizontal distances between 2 and 3, write all in the columns respectively ruled for the purpose. Do the same when the instrument is at C, D, E, and F; and you will then be furnished, by the field-book, with sufficient data, both to ascertain the difference of level between the points 1 and 7, and to represent the contour of the surface by a proper section.

To guard against the error arising from unequal curvature and refraction at the back and forward stations, direct the assistant to place the staff at equal distances from the instrument, which he can do with sufficient accuracy, by pacing the ground as he proceeds from the back to the forward station, without any additional loss of time. For instance, in proceeding with the staff from 1 to 2, the assistant can pace from 1 to A, and an equal distance from A to 2, at which he should place the staff.

B.Sight.	F.Sight.	Rise.	Fall.	Red.lev.	Dist.	Observations.
				0000		
5.75	2.41	3.34		3.34	300	Here, as in the last section, the datum line is drawn from the commencement of the line.
6.22	2.84	3.38		6.72	200	
7.11	3.07	4.04		10.76	310	
4.21	3.22	0.99		11.75	248	
2.61	8.91		6.30	5.45	312	
1.20	6.13		4.93	0.52	180	
27.10	26.58					
26.58						
00.52						



By referring to the second last figure, it will be seen that the back exceeds the fore sight by 3.34 feet, which shews a rise of so much from 1 to 2: it will also be seen that the staff reads more at station 2 than at station 3, by 3.38 feet, which is a further rise; therefore the total rise from 1 to 3 is the sum of these two ascents, namely, 6.72 feet. Again, station 4 is higher than station 3, by 4.04 feet, which shews a continuous rise from 1 to this point, amounting to 10.76 feet. The next step gives an additional height of 0.99 feet, which added to the former, gives 11.75 for the entire rise from station 1 to the summit of the hill at station 5. In the next distance we have a fall of 6.30 feet from 5 to 6, which must be deducted from the summit

[illegible]

[illegible]

[illegible]

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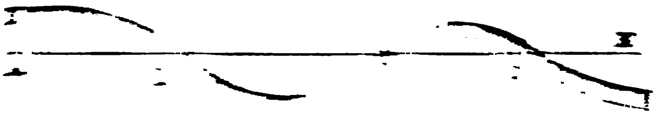

[illegible] line should [illegible]

[illegible] turnpike road, [illegible] requiring a graded section, you should invariably use a chain divided into feet, the vertical distances being given in feet. It would also be well to draw the section, so that the horizontal scale may be some aliquot part of the vertical.

You must be careful to write the several dimensions in the horizontal and vertical lines, in a legible hand.

In keeping the field-book, a separate column is sometimes devoted to the bearings. In the column for remarks, the bench-marks must be carefully written, as they, in connexion with the datum line, are most essential, not only for the subsequent laying out of the work in detail, but also for comparison in running trial or check-levels. These bench-marks should be permanent, and not easily destroyed or defaced, as in the course of the work it may be necessary to have reference to them.

A particular spot on a solid rock, on the stump of a tree, mile-stone, &c. would answer the purpose. The locality of these bench-marks should be well described in the field-book, that no doubt may afterwards arise about their identity. Whenever you change your direction, the angle it makes with the last direction should be registered in the field-book. Or, it would answer equally well to take the bearing of each direction with the meridian. Sometimes a separate column is devoted to the bearings, but they may as well be entered in the column headed 'Remarks,' in which are also written the crossings of hedges, brooks, rivers, roads, lanes, canals, &c., with a rough sketch, which will be of considerable service.

The following example, which is part of a contract section for a railway, will sufficiently illustrate the whole process of levelling and plotting, as practised by the best and most scientific engineers. The distances are

given in feet, and the elevations and depressions in f
and decimals.

From the explanation given of the preceding fi
books, the following, which is similar, requires littl
none. Any part that may require explanation sh
adverted to immediately after the field-book, for
part of the work all the incidental remarks shall
served. The field-book will afford sufficient d
plotting a section of the line, which the pupil sho

Back S.	Fore S.	Rise.	Fall.	R. level.	Dist.	Remarks.
				90.32	BM	Height above high w
3.22	9.84	,,	6.62	83.70	20	at Church-street.
5.73	8.41	,,	2.68	81.02	31	
7.32	9.14	,,	1.82	79.20	41	
9.41	10.31	,,	.90	78.30	160	Curve in road.
6.78	9.41	,,	2.63	75.67	217	
10.13	7.16	2.97	,,	78.64	237	B M on bottom of
5.14	4.65	.49	,,	79.13	447	
7.16	8.16	,,	1.00	78.13	910	
4.05	4.98	,,	.93	77.20	1476	
5.98	6.13	,,	.15	77.05	2566	
6.12	6.67	,,	.55	76.50	3450	B M opposite
3.77	8.77	,,	5.00	71.50	5760	
6.60	12.14	,,	5.54	65.96	7576	
3.76	6.36	,,	2.60	63.36	8730	
6.44	11.77	,,	5.83	57.53	9471	B M near Ch
2.67	5.67	,,	3.00	54.53	9567	
6.24	5.22	1.02	,,	55.55	9673	
5.20	6.20	,,	1.00	54.55	10034	
4.32	5.68	,,	1.36	53.19	12765	On bank of r
6.31	6.98	,,	.67	52.52	13984	
7.14	5.16	1.98	,,	54.50	15763	
6.16	9.27	,,	3.11	51.39	17371	
3.55	6.33	,,	2.78	48.61	18971	B M centre
5.37	6.16	,,	.79	47.82	19371	
6.20	8.67	,,	2.47	45.35	20438	
8.77	13.67	,,	4.90	40.45	23691	
6.70	6.77	,,	.07	40.38	30671	
5.44	9.37	,,	3.93	36.45	36943	
9.67	4.36	5.31	,,	41.76	41736	B M at bo
4.96	2.77	2.19	,,	43.95	48976	
3.98	6.76	,,	2.78	41.17	51754	
6.79	6.67	.12	,,	41.29	56982	
8.69	7.35	1.34	,,	42.63	67341	
8.41	8.10	.31	,,	42.94	76437	
3.76	4.37	,,	.61	42.33	79763	
5.48	6.44	,,	.96	41.37	81432	
6.37	8.45	,,	2.08	39.29	83743	
3.44	5.67	,,	2.23	37.06	94364	B M
227.23	279.99	15.73	68.49			

The foregoing field-book consists of six columns, besides a column for remarks. The first on the left hand, marked 'Back S.' is appropriated to the back sights; the next contains the fore sights; the third contains the rise between the back and fore stations, that is, the difference between the numbers in the first and second columns, where the former exceeds the latter; the next in order contains the amount of falls between the stations, that is, the difference between the numbers in the first and second columns, where the latter exceeds the former; the fifth column contains the reduced level, which gives the surface of the ground. It is found thus: having levelled from high-water mark to the bench-mark, at the commencement of the line, it was found to be 90.32 feet; that is, the point C is 90.32 feet above the high water line AB, which is here the datum line; and as there is a fall of 6.62 feet in the distance of 20 feet, we deduct 6.62 from 90.32, and the difference (83.70) is the height at the end of the first 20 feet above the datum line. In the next there is a fall of 2.68 feet, which is deducted from the last remainder (83.70), and the difference (81.02) gives the height at the end of 31 feet above the datum line. In this manner we deduct every successive fall from the last reduced level. The first number that occurs in the column headed 'Rise,' is 2.97 feet, which is added to the last reduced level (75.67); and to the sum (78.64) we add the next rise (.49), and so we continue, adding all the numbers in the column headed 'Rise' to, and subtracting all the numbers in the column headed 'Fall' from, the last reduced level, writing the several sums and differences opposite their respective distances, which occupy the sixth column. The column headed 'Remarks,' is intended for any observation the engineer may think proper to make.

The section is plotted from the fifth and sixth columns, in the following manner. Let the pupil supply the letters.

AB is drawn to represent the high water or datum line, upon which all the horizontal distances are laid off from the point A, the several distances being found in the sixth column. Then at the end of all the respective distances, perpendiculars are erected to the datum line, and upon these perpendiculars the respective reduced levels are laid off, as found in the fifth column. Then the line joining the extremities of these vertical distances will represent the surface of the natural ground.

In a section of this line, it will be seen that the excavation at one end is very far from the embankment at the other extreme end of the line: in this case it might be cheaper to procure filling material somewhere convenient to the embankment.

It has been said before, that the difference between the back and fore-sights must always be equal to the difference of level between the extreme points of the line; also equal to the difference between the sums of the rises and falls. It should also be equal to the difference between the assumed datum line and the last reduced height.

MOUNTAIN BAROMETER.

Altitudes are found by means of an instrument termed the Mountain Barometer, from its being chiefly used in determining the heights of lofty mountains. The improved mountain barometer has a vernier, by means of which you can read off the height of the mercury in the tube to $\frac{1}{1000}$ part of an inch; it has a thermometer attached to it, which indicates the temperature of the fluid. You must be supplied with a detached thermometer to denote the temperature of the atmosphere at the time of observation. In some barometers, the surface of the mercury in the cistern is brought, by means of a screw, to the zero of the instrument, which marks the height at which it stood there when the scale was first graduated. This is not at all considered of any peculiar advantage.

In other barometers having no means of effecting the last adjustment, the cistern being entirely enclosed, an allowance is made to reduce the reading on the scale to what it would have been, if the mercury in the cistern had been adjusted to zero. This correction of the height of the mercurial column depends on the relative capacities of the cistern, and the bore of the tube. As an example, let us suppose the interior diameter of the tube to be .1, its exterior .4, and the diameter of the cistern 1 inch; then the ratio of the areas of the surfaces will be 1 to 84, that is, 1 to (100—16.) The difference between the observed reading of the barometer and that of the neutral point,* is to be diminished in the proportion of 84 to 1, as found above; and the quotient added to the observed reading when above the standard, and subtracted when lower. The correction for the capillary attraction of the glass tube is generally allowed for by the maker in laying off the neutral point, and therefore it needs not to be considered.

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* The neutral point (marked N.P.) is the height at which the mercury stood in the tube, above the zero mark of the cistern, when the barometer was first made.

The correction for capacity is usually found by first pouring mercury into the tube, to the height, say of 14.6 inches; then the same quantity is put into the cistern, which is found to rise .174. The capacity is therefore as 14.6 to .174, or 84 to 1, which the maker generally marks on the instrument.

In finding the height of a very high mountain, the best plan would be to let two persons take simultaneous observations at the points whose difference of altitudes is required, as no reliance can be placed on observations made at different times, removed from each other by long intervals, especially in changeable weather. If, however, the mountain be not so high as to require a long time to travel from the top to the foot of it, the result will be sufficiently accurate by successive observations taken by the same person.

Mr. Bailey has given a very simple formula, derived from a rule given by La Place, for finding comparative altitudes. Mr. Bailey reduces the French measures employed by La Place to English measure (feet), and also the temperature to Fahrenheit's thermometer. Put t for the temperature of the air at the lower station, and t' at the upper, r and r' that of the mercury, B the barometer at the lower station, and B′ at the upper, and L the latitude of the place of observation, also x the required altitude; then

$$x=60345.51\times\{1+.001111\,(t+t'-64^\circ)\}\times\text{log. of}$$
$$\left\{\frac{\beta}{\beta'}\times\frac{1}{1+.0001\,(r-r')}\right\}\times(1+.002695\text{ cos. }2\text{ L}).$$

To express this in a more concise form, let A denote the log. of the two first, C of the last term, and B that of $\frac{1}{1+.0001(r-r')}$; the last formula becomes A+C+log. D; putting D=log. β—log. β'+B.)

The following form will answer for registering the observations:

OBSERVATIONS TAKEN FROM A MOUNTAIN BAROMETER.

$$\left.\begin{array}{l}\text{N.P.}=30.200\\ \text{Cap.}=\frac{1}{6839}\end{array}\right\}\text{Lat. }52^\circ\ 30'.$$

Station.	Attached Thermom.	Detached Thermom.	Observed Barometer.	Corrected for Capacity.	Corrected Barometer.	Difference of level	Observations.
High water mark	62°	59°	30.405	.003	30.408 B		
Court-house	61	58	30.276	.000	30.276 B		

The difference between the observed reading of the barometer and that of the neutral point, is .205, which being divided by 84, gives .003 nearly, for the correction for capacity: this correction, added to the observed barometer, gives the quantity in the column, headed corrected barometer.

The following calculation for the altitude, founded on the above observations, will be sufficient to exemplify the formula:

$t+t'=59+58=117$, $117-64=53$, $53\times.001111=.058883$

$r-r'=62-61=\ \ 1$; then $1+.058883=1.058883$; and

$$\begin{array}{lr} \text{log. }60345.51=4.7806449 \\ \text{log. }1.058883=0.0241092 \\ \hline & 4.8047541=\text{A} \\ \text{log. }\beta=30.408\ \ 1.4837078 & \end{array} \left\{\begin{array}{l} 52^\circ.30\times2=105^\circ=2\varphi \\ (1+\cos.2\varphi)\times.002695= \\ 1.0254147\text{ and} \\ \text{log. }1.0254147= \\ \qquad 0.0107336=\text{C} \end{array}\right.$$

$$\left\{\begin{matrix}\log.\ \beta' \\ +B\end{matrix}\right\} = \log. 30.276 + B = 1.4810985 + 0 - 0000434$$

$$= 1.4810551 = \log.\ \beta' + B.$$

$$\begin{array}{rl}
\log.\ \beta = & 1.4837878 \\
\log.\ \beta' + B = & 1.4810551 \\
\hline
 & 0.0027327 = D \\
\log.\ D = & -3.4365919 \\
A = & 4.8047541 \\
C = & 0.0107336 \\
\hline
 & 2.2520896 - 108.687 \text{ feet} = \text{altitude.}
\end{array}$$

Doctor Hutton has given a rule for finding the heights of mountains, by means of the mountain barometer. It is as follows :

First, correct the heights of the mercury, or reduce them to the same temperature, increasing the colder or diminishing the warmer by $\frac{1}{9600}$ part, for every degree of difference between them, as shewn by the attached thermometer.

2nd. Take the difference of the common logarithms of the heights of the barometer, thus corrected, setting off four figures from the left hand for integers, which will be an approximate height in fathoms.

3rd. Correct the number last found for the atmospheric temperature, shewn by the detached thermometers, as follows :—for every degree that the mean of the two differs from 31°, take so many $\frac{1}{435}$ parts of the fathoms above found, and add them if the temperature be above 31°, but subtract them if below, for the true difference of altitude in fathoms. In this rule there is no correction for latitude.

Let us resume the last example :

$\frac{30.278}{9600}=.003$
30.278 add
30.281
30.408 log. 1.4829878
30.281 log. 1.4811702
Approx. alt. faths.$=$0.0018.176
1.11
19.28
6

58
59
2)117
58.5 mean.
31 subtract.
27.5
$\frac{18}{435}\times{\cdot}27=1.11$

115.68 feet. Altitude.

This rule of Doctor Hutton's gives only an approximate result. It is the easiest and shortest for practice, and may answer tolerably well, except in cases where great accuracy is required.

The following formula may be used in finding the heights of mountains by means of the mountain barometor. Let h and h' denote the observed heights of the barometer at the lower and upper stations respectively; T and T′ the temperatures of the mercury at those stations; e the excess of the sum of the temperatures of the air above 100° Fahr. Then the approximate formula is, $x=(54471+58e)\,\frac{h-h'}{h+h}-2.6\,(T-T')$, x being the difference of level of the two stations in feet.

Generally the correction for the temperature of the air and of the mercury will be very small: if we omit these as inconsiderable, we have the following rule: Divide the difference of the barometric heights by the sum, and multiply the quotient by 54470; the resulting number will be the difference of level of the two stations in feet.

The exact logarithmic formula is, $x = 20100\,[1 + .001111(t+t')] \times \log. \frac{h}{h'\,[1+.0001(T-T)]}$, t and t' being the excesses of the temperatures of the air at the two stations above the freezing points, and x the difference of level in yards.

This formula is calculated for the mean temperature of this kingdom. When the latitude is much different, a correction for it is also necessary.

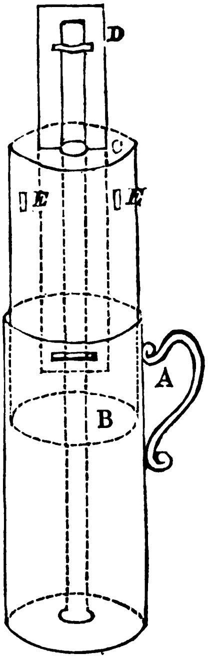
A description of an instrument, invented by Sir John Robinson for finding altitudes, may be seen in the Mechanic's Magazine for October, 1839.

The author had the pleasure of hearing a paper read by Col. Sykes, at a meeting of the British Association, descriptive of a very simple instrument invented by himself, and practised extensively in India. This paper is published.

This instrument is similar to a shaving box, which is filled to the height of four or five inches with pure water, the temperature of which, in a boiling state, as ascertained by the common thermometer, will give a good approximate result.

The accompanying sketch, taken from a pamphlet published by Colonel Sykes, with his description of the apparatus used by him, will at once shew its applicability to the purposes of ascertaining altitudes. Mr. Prinsep has computed tables to facilitate the computation of altitudes by Col. Sykes' apparatus.

The following tables, taken from the paper above alluded to, always give results less than those obtained from barometrical observations:



A is a common tin pot, 9 inches high, by 2 inches in diameter; B is a sliding tube of tin, which may be moved up and down in the pot: the head of the tube is closed, but has a slit in it, C, to admit the thermometer passing through a collar of cork, which shuts up the slit when the thermometer is placed. D is a thermometer, with so much of the scale left out as may be desirable. E E are holes for the escape of steam. The thermometer is fitted into the aperture in the lid of the sliding tube, by means of a collar of cork, and the tin sliding tube pushed up or down, to admit of the bulb of the thermometer being about two inches from the bottom of the pot. Before a thermometer is used for this purpose, the boiling point must be correctly marked for the level of the sea by a number of careful observations, noting the difference, if any, as an index error. The inventor recommends to have two or more thermometers, which have been well tested, and also to register the temperature of the air at the time of making all the observations.

The following tables will enable one, in a few minutes, to find the height of any mountain, to a degree of accuracy sufficient for most purposes:

TABLE I.

To find the Barometric pressure and elevation corresponding to any observed temperature of boiling water between 214° *and* 180°.

Boiling point of water.	Barometer modified from Tredgold's formula.	Logarithmic differences of fathoms.	Total altitude from 30.00 in. or level of the sea.	Value of each degree in feet of altitude.	Proportional parts for one-tenth of a degree.
			Feet.	Feet.	Feet.
214°	31.19	00.84.3	–1013	–505	...
213	30.59	84.5	507	–507	...
212	30.00	84.9	0	+509	...
211	29.42	85.2	+509	511	51
210	28.85	85.5	1021	513	...
209	28.29	85.8	1534	515	...
208	27.73	86.2	2049	517	...
207	27.18	86.6	2566	519	52
206	26.64	87.1	3085	522	...
205	26.11	87.5	3607	524	...
204	25.59	87.8	4131	526	...
203	25.08	88.1	4657	528	...
202	24.58	88.5	5185	531	53
201	24.08	88.9	5716	533	...
200	23.59	89.3	6250	536	...
199	23.11	89.7	6786	538	...
198	22.64	90.1	7324	541	54
197	22.17	90.5	7864	543	...
196	21.71	91.0	8407	546	...
195	21.26	91.4	8953	548	...
194	20.82	91.8	9502	551	55
193	20.39	92.2	10053	553	...
192	19.96	92.6	10606	556	...
191	19.54	93.0	11161	558	...
190	19.13	93.4	11719	560	56
189	18.72	93.8	12280	563	...
188	18.32	94.2	12843	565	...
187	17.98	94.8	13408	569	57
186	17.54	95.3	13977	572	...
185	17.16	95.9	14548	575	58
184	16.79	96.4	15124	578	...
183	16.42	96.9	15702	581	...
182	16.06	97.4	16284	584	...
181	15.70	99.9	16868	587	...
180	15.35	98.4	17455		59

The fourth column gives the altitude in feet.

TABLE II.

Table of Multipliers to correct the approximate height for the temperature of the air.

Temperature of the air.	Multiplier.	Temperature of the air.	Multiplier.	Temperature of the air.	Multiplier.
32°	1.000	52°	1.042	72°	1.083
33	1.002	53	1.044	73	1.085
34	1.004	54	1.046	74	1.087
35	1.006	55	1.048	75	1.089
36	1.008	56	1.050	76	1.091
37	1.010	57	1.052	77	1.094
38	1.012	58	1.054	78	1.096
39	1.015	59	1.056	79	1.098
40	1.017	60	1.058	80	1.100
41	1.019	61	1.060	81	1.102
42	1.021	62	1.062	82	1.104
43	1.023	63	1.064	83	1.106
44	1.025	64	1.066	84	1.108
45	1.027	65	1.068	85	1.110
46	1.029	66	1.071	86	1.112
47	1.031	67	1.073	87	1.114
48	1.033	68	1.075	88	1.116
49	1.035	69	1.077	89	1.118
50	1.037	70	1.079	90	1.121
51	1.039	71	1.081	91	1.123

To use these tables, let the thermometer be boiled at the top and foot of the mountain, whose height you are required to determine; deduct the number in the column of feet opposite the boiling point below, from the same of the boiling point above, and the difference will give the approximate height, which must be multiplied by the number opposite the mean temperature of the air, in Table II., for the correct altitude.

The following example, taken from Col. Sykes' paper, will illustrate the rule:

		Feet.
Boiling point at summit of hill, Fort of Purundhur, near Puna ...	204°.2	=4027
Boiling point at Hay Cottage, Puna ...	208°.7	=1690
	Approximate height	=2337

Temperature of the air above 75°
Temperature of the air below 83

2)158

mean=79. Multiplier 1.098

Then 2337 × 1.098=2566 feet.

Opposite 204° in the first table is the number 4131, in the column headed "total altitude from 30.00 in. or the level of the sea;" and the number opposite 205 is 3607; their difference 524, being multiplied by .2, gives 104, which must be deducted from 4131, leaving 4027 feet, answering the boiling point 204.2. Again,

The number answering ... 208° is 2049
And the number answering ... 209 is 1534

difference 515

Then 515 × .7=360, and 2049−360=1689, which by these tables is the number answering 208.7°, and not 1690.

The apparatus employed by Colonel Sykes, as described and represented above, may be had at Newmans, opticians, Regent-street, London. It is cheap, easily managed, and not liable to accidents or injury. Mr. Princep's tables render the calculations easy and expeditious, a few minutes being sufficient to determine the height of any eminence, after having ascertained the boiling points of the thermometer above and below.

As a practical application of the influence of pressure on the boiling point of water, the following rule is given for finding the heights of mountains by boiling water:

Boil pure water in an open vessel at the bottom of the elevation, and observe with the thermometer the point at which it boils. Boil it again at the top of the mountain, and observe with the thermometer the point at which it now boils: the difference of temperature, multiplied by 530 feet, will give a close approximation to the height of the upper above the lower station.

This will give an approximation; but if greater accuracy be required, it will further be necessary to correct for the difference of the temperature of the air at the two stations, in the following manner:—Add the temperature of the air at the stations, and subtract 64 from their sum; multiply the remainder by one thousandth part of the height found, and this will be the correction to be added to the height formerly found. The result thus found will still require a slight correction for the figure of the earth and latitude of the place, but this does not amount to more in our latitude than an addition of about two feet in a thousand, which forms a second correction.

To illustrate the mode of deducing heights from the boiling point, as we have given it, we take the following example:—

Water boils on the top of Ben Nevis at 203.8°, while at the side of the Caledonian Canal it boils at 212°, the temperature being 30° on the summit of the mountain, and 35° below. In order to determine the height—

From	212°	To	30°
Take	203.8°	Add	35°
There remains	8.2°	Sum	65°
Multiply by	530	Subt.	64°
	2460	Rem.	1° mult. by 4.346
	4100	Lat.	56° nearly
		Mult.	4.350
	4346.0 first approx.	by	2
			8.700

4346 first approx.
4 first correct.

4350 second approx.
8.7 second correct.

4358.7 third approximation for the height.

This method, however, is seldom susceptible of so high a degree of accuracy, even with the most carefully conducted experiments. This method has been taken from the Encyclopedia Britannica.

The barometer is furnished with a vernier, by which the reading may be carried to a greater degree of minuteness than it otherwise could be without such an adjunct. The following formula is general for any degree of minuteness to which we may wish to carry the reading on the instrument:

If $n-1$ divisions on the arc or scale be divided into n divisions on the vernier, then this vernier shews $\frac{1}{n}$ part of the divisions on the limb, because $1-\frac{n-1}{n}=\frac{1}{n}$. This formula applies to circular as well as to straight instruments. Thus, if we suppose an arc to be divided into single degrees, then the vernier having an extent equal to 59 of these degrees, divided into 60 equal parts, it necessarily follows that each part on the vernier will be $\frac{1}{60}$ less than the one on the arc. Now $\frac{1}{60}$ part of a degree being equal to 1′, it obviously follows that such a vernier would, by the coincidence of any two lines—one on the vernier with one on the scale or arc—shew single minutes. A vernier, however, of the extent of so many primary parts on the instrument, would be inconveniently long. To obviate this inconvenience, the arc, as in the theodolite in common use, is divided into half degrees of 30′ each; then a vernier of the extent of 29 of these half degrees, divided into 30 equal parts, will also read to minutes. Further, if 1° be divided into 6 equal parts of 10′ each, and if 59 of these parts be divided into 60 on the vernier, then it will follow that $\frac{10'}{60}=\frac{1'}{6}=10''$. From this it appears that an instrument thus divided shews 10″ directly, on which the reading may be carried on to 5″ by estimation.

RECONNOISSANCE.

In seeking the best route for a turnpike road, railway, or canal, so far as level is concerned, the engineer's labour is much abridged by duly considering the operations of nature, in the formation of mountains and valleys, which, at first sight, would seem to present an endless variety of forms and combinations. Upon a closer and more careful inspection, however, we shall find that the two grand features of almost every country, present lines whose sinuosities are not very abruptly or violently distorted. The water courses form the lowest lines of the valleys, while the summits of the ridges inclosing these valleys, form the highest.

These two classes of lines, visibly delineated on the surface of every country, are remarkable for being lines of greatest declivity of the surfaces to which they belong.

These two facts being known, the engineer, after a careful examination of the country, will feel no difficulty in finding the best level for his intended line of road or canal.

From the general configuration of any segment of the earth's surface, we at once see that lines of communication necessarily divide themselves into two classes. First, it may be necessary to form a line of communication between two points situate in the same valley. Secondly, it may be required to open a line of communication between two places separated by a dividing ridge. In seeking the best direction in the former case, the engineer is not to go out of the valley; in the latter case, he must pass the dividing ridge at its lowest point, it being a loss of time and labour to look for any other point at which to pass higher up the ridge.

When an engineer is called upon to ascertain the best line of road or canal, a good map of the country through which the road or canal is to run, will assist him in his reconnoissance, as it contains with sufficient accuracy, the water courses, which usually give direction to the valleys and dividing ridges, and which last are generally shewn on such maps.

If upon examining the map of any portion of a country, you see the water courses diverging from any particular locality, you may, without farther trial, conclude that that locality occupies the highest position; being led to this conclusion from the well known fact, that water runs from a higher point to a lower. Again, if you see on the map several water courses converging towards a particular point, the inference to be drawn from this geographical delineation is, that that point occupies the lowest position in that portion of the country. This we know also from the well known property of fluids, by which they invariably seek the lowest level. These are properties and established facts, to which the engineer should particularly attend; indeed every common observer is aware of them, though men of experience sometimes neglect taking advantage of the instruction they afford.

After a general examination of the features of the country, for the purpose of ascertaining the best probable directions, you next level in these directions, and compare the results, which will determine the particular direction to be taken.

RAILWAY SURVEYING.

After the engineer has determined the direction of the proposed road, a surveyor is generally employed to make a survey of all the inclosures through which it passes. Sometimes, such surveys are executed with the chain only, which in many cases answers very well; but we would recommend invariably to use the theodolite and chain.

Let EF be the line of road to be measured. First, measure with great care the base line AB, according to the directions given before; then returning to the point A, where a flag staff is erected, ascertain the angle the base line makes with the magnetic meridian, which you will register in the field-book. Next measure the angles 21*a*, 31*a*; then chain from station 1 to station 2, taking offsets to the left as you proceed; in the same manner, chain from station 1 to station 3, taking only one offset to the boundary line, being perfectly straight and parallel to the station line 1, 3. These measurements being registered in the field-book, the next thing to be done is to measure the angle 1, 2, 5, and chain from station 2 to station 5, taking offsets to the left and right, as you go along. In like manner, take the angle

1, 3, 4, and chain from 3 to 4, and measure two offsets to the right. In measuring the base line, false stations should be left at the crossing of the fence *a*, also at *b*, *c*, *d*, *e*, &c., and at every point at which a fence crosses it. The angles which have been taken, and the measurement of the lines 3, 4, and 2, 5, mark the position of the fence crossing the line at *a*. Next, take the angles 6, 4, 20, and 4, 6, 7; then chain the lines 4, 6; 4, 20; 6, 7. Chain the fence passing through *a*, as also that connecting 7, 20, which will serve to check the work, when plotted. The chainage of these check lines should never be neglected.

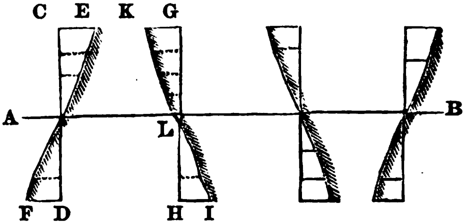
The next thing to be done is to measure the angle 6, 5, 9; and chaining from 5 to 9, take the angles 5, 9, 8, and then chain the line 9, 8, taking care to measure the offsets as you proceed.

Any one acquainted with the common principles of geometry can never be at a loss to know the sides and angles necessary to be measured, in order to mark the position and extent of the different inclosures along the line. A fewer number of observations and chain measurements might often mark the position of the several lines; but the extra work answers as a check to prove the correctness of the several operations, which is a duty never to be neglected.

When, in the progress of the work, you are obstructed by a wood, lake, house, or other obstacle, then you measure across the obstruction by the method taught in the part of the work devoted to parish surveying. If your base line be not ranged out with poles, the compass would be a tolerably correct guide. Take the bearing of the line approaching the obstacle, and after having passed it, take the bearing of the line receding from it: if these coincide, it establishes the correctness of the work; but if there be a considerable difference between the two bearings, an error must have been committed in the work, which must be corrected by going over the same ground again. It would be desirable to compare the bearing of the base line at the subsequent stations, with its bearing as ascertained at the commencement of the survey, as their equality would form a presumptive evidence of the correctness of the work.

CROSS SECTIONS.

When the ground slopes at right angles to the line of road, cross sections must be taken at right angles to it; and this cross section as well as the longitudinal section, must be drawn to a large scale, to guide the working engineer in his operations. The cross sections may be taken at the same time you are taking the levels of the main line. After having brought up the levels to any point of the line where you think it necessary to take a cross section, place a picket firmly in the ground, at which point place the staff, and without removing the instrument, take the level at that point, and also at two points at right angles to the line there; and the distance between these two last points being measured, you will have sufficient data for laying down the cross sections along the line. If you do not think it sufficient, from the nature of the ground, take the levels of several points on each side the main line, at right angles thereto, which, when plotted, will give the exact contour of the



line. AB is the main line, CD is at right angles to AB, the point E is lower than the point A in the main line by the measure of CE, and the point F is higher than the point A in the main line by the measure of FD. But K is higher than L by the distance KG, while I is lower than L by the distance HI. In surveying the main line AB, it would be well to take the station lines at right angles to it, as the line, by this means, is more easily surveyed and levelled at one operation than when it is done by means of a series of triangles. Whereever the ground, in the cross section, deviates much from a straight line, the staff is placed there, and the height or depression ascertained. These are represented by the dotted lines in the above sketch. The intersections of the cross and main line will answer as so many temporary Bench Marks.

These surveys should be very neatly and correctly protracted on a sufficiently large scale, say three, four, or five chains to an inch for the ground plan, and 30 or 40 feet to an inch for the vertical section. Should the line of road cross a river, the greatest height of the floods, the velocity of the water, and the sectional area of the river should be stated. When the line passes a bog or morass, the capabilities of drainage, as well as the depth of each, should be ascertained.

In making a survey of a common road, railroad, or canal, the surveyor or engineer cannot be too particular in detailing every thing connected with it, as it is only from such minute details of all the circumstances connected with the line, that he will be enabled to report on the peculiar advantages or disadvantages attendant upon it, by which the parties interested are entirely guided in making a choice.

ROADS.

Having given directions before, under the head 'Reconnoissance,' for performing all the preliminary operations required, before the road is actually commenced, it is unnecessary to repeat them here. It is necessary however to add, that in laying out a common road, the engineer is not so strictly restricted, either in curvature or slopes, as in a rail-road. He should, notwithstanding, as far as economy of expenditure will permit, adhere to two general rules: namely, to make choice of the straightest line that connects two points, and the one that presents the best levels. These two characters, with a hard, dry, and smooth surface superadded, constitute the best line of road.

Very many engineers are of opinion that a perfectly level road is not always the best for every species of draught. Telford, Walker, Paterson, and Marshal concur in this opinion; alleging as a reason, that slight and short alterations in the surface are serviceable to horses moving with tolerable speed; as in ascending a hill, one set of muscles is in active operation, while another set is at rest; and in descending, the muscles which had been before at ease, are now brought into action. These gentlemen are supported by the evidence of some of the most experienced coach drivers, who assert that a horse dragging a load on a level road will feel much more fatigued and exhausted, after having travelled a given distance, than he will after having passed over an equal distance with a gentle acclivity and declivity here and there. For this reason Mr. Paterson recommends that even the length of one mile should not be perfectly level, though easily obtained. Notwithstanding these high authorities, we would always recommend the most perfect level that can be obtained, consistently with the shortest distance that the face of the country will admit of. Mr. Stephenson, an eminent engineer, submitted this case to the consideration of a medical friend, eminent for his superior knowledge of comparative anatomy, Doctor Barclay of Edinburgh, who returned the following answer: "My acquaintance with the muscles by no means enables me to explain how a horse should be more fatigued by travelling on a road uniformly level, than by travelling a like space upon one that crosses hills and hollows. But it is demonstrably a false idea, that muscles can alternately rest and come into motion in cases of this kind. The daily practice of ascending heights, it has been said, gives the animal wind and enlarges his chest. It may also with equal truth be affirmed, that many horses lose their wind by this sort of training, and irrecoverably suffer from imprudent attempts to induce such a habit." The Doctor ascribes "much to prejudice originally with the man continually in quest of variety, rather than the horse, who consulting only his own ease, seems quite unconscious of Hogarth's line of beauty."

In laying out a road towards a river, stream, or any place requiring a bridge or tunnel, it is obviously advantageous to approach it at right angles. This rule will apply in regard to any part requiring to be crossed by an aqueduct: as when a bridge or aqueduct passes obliquely, skew arches are to be constructed, which should be avoided in every possible way, being much more expensive and less substantial than direct arches. When it becomes necessary to lay out a road over a steep hill of considerable height, much skill is required to keep the slope uniform, and within moderate limits, which can only be done by a winding or zig-zag course. Great heights may be ascended in this way, and by increasing the length of the road, its inclination may always be kept within the maximum degree of steepness.

The natural obstacles which oppose themselves to the making of the best line of road, are hills, valleys, water-courses, bogs, marshes, and want of good materials. Therefore the nature of the soil, or the different strata, should be shewn, on the section, over all apparently favourable lines; which may be ascertained by boring, by which the engineer will be enabled to point out the slopes at which the cuttings and embankments will stand, and calculate the contents and expense.

When a hill lies between two points which are to be connected, the road must get such a slope as that, in descending, the accelerating force of gravity shall not affect the carriages travelling with the usual speed. The slope that would render it necessary, for the safety of carriages, to diminish the speed in descending, would also tend to retard the speed in ascending. Therefore the slope must be within given limits; that is, it shall not be greater than the angle of friction. And as the angle of friction varies according to the materials forming the road covering, the slope therefore may vary; but in this enquiry we shall restrict ourselves to a well formed M'Adamised road, upon which the inclination should not exceed 1 in 35, down which a carriage may be driven with safety at the rate of twelve miles an hour. The angle of friction can only be ascertained by actual experiment. By allowing a carriage to descend on a road of variable inclination, until the friction shall overcome the force that caused the motion, the angle of friction may be determined: it may also be determined on a level road, by the force of traction required to set the carriage in motion. Sir Henry Parnell, in his excellent work on roads, gives the results of experiments tried on the road between London and Shrewsbury. The instrument used was the invention of Mr. Macneil, the waggon employed in the experiment weighing 20 cwt. The results of the trials on different sorts of roads are as follow:

		℔
1.	On well made pavement the draught is ...	33
2.	On a broken stone surface, or old flint road	65
3.	On a gravel road	147
4.	On a broken stone road, upon a rough pavement foundation	46
5.	On a broken stone surface, upon a bottoming of concrete formed of Parker's cement and gravel	46

Here it may be seen, that in the first case, the angle of friction is represented by $\frac{33}{2240}$, or $\frac{1}{68}$ nearly; which shows that the slope in this case should not exceed one perpendicular to sixty eight in length: for the same reason, in numbers 2 and 3, the slope should not exceed 1 to 35, and 1 to 15 respectively, and in numbers 4 and

5, 1 to 49. The maximum slope is limited by the equality of the amount of friction and force of gravity along the road. When it becomes necessary to connect two points, one higher than the other, or to pass a hill at a higher point than either of the extreme ones which are to be connected, the direct line should be followed as long as the slope is found to be within the limits above prescribed by the experiments on different road materials. But when, on account of some intervening obstacle, it becomes necessary tc change the direction, a circuitous one with a slope within the prescribed limits, must be chosen, which may be continued till the surface of the country shall warrant a departure from it towards the point to be arrived at; every change of direction should be part of a circle. In laying out a road in a hilly country, in which it is necessary to ascend from a lower to a higher point, due care should be taken that, after having ascended a part of the height, the road should never descend till it reach the highest point to be arrived at, as an up and down direction imposes unnecessary labour on the horses that travel over it. Sir Henry Parnell mentions a case on the road between London and Barnet, "on which the total number of perpendicular feet that a horse must now ascend is upwards of 1300, although Barnet is only 500 feet higher than London." This up and down direction is owing to a wish to keep in a direct line.

The old roads in the mountainous districts of Ireland furnish numerous instances of the tenacity with which men, in former days, adhered to the universal practice of making all their roads perfectly straight. When they arrived on the side of a hill, and wanted to gain a point on the opposite side of an intervening valley, the practice was to descend into the valley, and ascend on the opposite side to the required point. A vast improvement on this old practice is exemplified in the roads connecting the town of Tralee with those of Dingle and Cahersiveen. Many other roads in the hilly districts of Galway, Antrim, Cork, and Kerry, prove the superior skill of modern engineers, as compared with old road makers.

In crossing a valley, the road should be carried round the bosom of the hill, by which the up and down direction, so laborious to draft horses, may be avoided. In place of carrying a road right over a hill, it should go round the base. When a road runs through a perfectly flat plain, it must be raised, otherwise it can never be kept dry or in good repair. It is of the utmost advantage to command a sufficient fall to carry off the water: an inclination of 1 in 100 would be sufficient for the drainage.

In taking levels, with a view to ascertain which of two or more lines is best adapted for a line of road, the engineer must be scrupulously careful to notice every circumstance, whether favourable or unfavourable, connected with it; such as the facility or difficulty of procuring good stone quarries or gravel pits convenient to the line, the number and magnitude of all the streams and rivers to be passed, the extent of bog or moor to be passed over, &c.

It has been said before, that in crossing a valley it is best to carry the line round the bosom of the hill; but if any part of the valley contract into a narrow ravine, the engineer, from motives of economy, might be induced to cross it by means of an embankment.

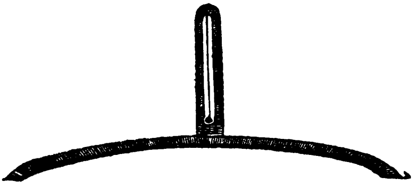
When two points are to be connected, between which lies a bog, marsh, or wet soil, of no great extent, it is sometimes advisable to avoid it, by taking a circuitous route, possessing a more solid bottom, and therefore more favourable for the construction of a good road. When a road is to run in the same direction as a river, but destined to connect two points situated on opposite sides of the stream, the engineer should carefully examine which of the two sides has the more solid foundation; which is more exposed to the action of the sun and wind; which presents more facilities of procuring good road materials; which has fewer secondary streams, and what point of the river is best suited for the erection of a bridge, as regards the approaches to it, the direction of the currents, the foundation for the works, the vicinity of roads already made, and the traffic already in existence, or likely to be created in the district. All these points should be carefully considered before he determines the line.

We could point out a variety of instances in Ireland of roads and bridges having been constructed without the least regard to these favourable circumstances. In the article devoted to the construction of rail-roads, we shall give instructions in detail, which are equally applicable to the making of common roads. To that article, therefore, we refer the reader for directions for equalising excavations and embankments; for making proper slopes; for drainage, &c. Under the head "Embankment" are instructions which apply here, and to which the reader is referred.

When the road-way is partly in excavation and partly in embankment, the excavation and embankment must be sloped as directed in the article on rail-roads; but when the slope of the natural surface of the ground on which the embankment is to rest, is so vertical as to endanger its stability, the whole natural surface must be made into steps, on which the embankment is raised in thin layers well rammed.

Drainage.—Without a thorough system of drainage, no road can be made sufficiently solid or substantial to bear any considerable traffic; therefore, due care must be taken to make such drains along the line as will carry off the water from the foundation, as well as that which glides from the surface. It is often necessary to convey the water in these side-drains through culverts crossing the roads, so as to communicate with the natural water-courses of the neighbourhood. The subject of culverts shall be treated hereafter.

In order that the rain-water falling on the road may flow off, the centre is usually raised six inches higher than the sides. The best curve to give the transverse surface is that of an ellipse; and to preserve the cross section uniform, the superintendent or overseer should procure a wooden guage resembling a semi-ellipse, by which he can try the surface curve of every part of the line as it proceeds. This curved apparatus should be surmounted by a plumb and line, by which the instrument is properly adjusted to the road, and an equal inclination from the centre secured. The capacity of the side-drains must be commensurate with the supply of water. As the washings



from the side-slopes would soon fill up the open drains along the part of a road in excavation, covered drains should be built either of stone or brick, with a smooth flagged bottom, and sides of rubble or brick masonry. The top then should be flagged.

Cross mitre-drains are made at intervals of 60 yards from each other, under the road-way. The plan of these drains resembles the letter V, the point at which the sides meet being in the centre of the road, and directed towards the ascent, and the opening of both branches so regulated as to give them a fall not exceeding 1 perpendicular in 100 base, a greater declivity being calculated to increase the velocity of the water to a degree injurious to the masonry. These drains are not required where the foundation is dry and sound; but where there are springs and a weak bottom, their use cannot be dispensed with. They are made like side-drains, but of smaller capacity. The side slopes of cuttings should be furnished with small surface drains, termed catch-water drains: they run obliquely up the slopes, and convey all the surface water into the side drains, through which it is still farther conveyed to the natural water-courses. These oblique surface drains prevent the side slopes from being furrowed and disfigured by heavy rains, which would soon wash down such quantities of earth as would choke up the side drains. Draining tiles are sometimes used for this purpose.

Care must be taken to make cross drains or culverts under the road, sufficientlyca pacious to carry off all the water from the side channels and covered drains. A very bad practice formerly prevailed, of giving the cross section of the road an inclination towards the natural fall of the ground, by which the water coming from the grounds commanding the road, soon made ample furrows across it, which rendered it impassable. The destruction in this way is very rapid in heavy falls of rain, and during thaws. Some engineers recommend a little inclination of the cross section towards the hill side; but in our opinion the cross section should not incline to either side.

It is an injudicious practice to make foot-paths on the side of the road adjacent to the side-cutting: they should always be made on the side adjacent to the embankment; here they are secure from the drippling to which they would be constantly exposed, if placed on the contrary side of the road. Where there is no side-cutting, the foot-path should be placed on that side which is rendered the greater thoroughfare, by its peculiar locality as regards a neighbouring house, village, town, or city—due regard being paid to aspect. The approach to a populous town or city may require two, for the use of pedestrians.

Before commencing the road surface, a thorough system of drainage must be pursued along the line, and where it passes over a wet soil, sufficiently broad and deep open drains must be cut on either side of the road, which is intersected at short intervals by cross or mitre drains, as the case may require. Sometimes the sub-soil, to a certain depth, is replaced by a better description; and where the bottom is composed of peat, or other yielding spongy substances, an artificial foundation, consisting of brushwood, is made, for the road-covering to rest on; without which, the surface would soon sink. Without this precaution, the road-covering will be constantly sinking, by which the road will require constant repairs, entailing heavy charges on the public, which a more systematic plan of construction would have prevented.

The breadth of the roadway and foot-path will depend on the traffic and intercourse. While the main roads connecting two populous cities, require a width of thirty feet at least, in all the parts distant from either, the near approaches would require a width of from fifty to sixty or seventy. The cross country roads need not much exceed the breadth of two of the ordinary carriages of the country. The foot-paths in the neighbourhood of towns or cities may vary from four to six or eight feet.

In departing from a straight line, the turn should invariably be a portion of a circle, to avoid an abrupt deflection. When a change of direction takes place in a road at the foot of a descent, the exterior side of the curve should be raised a little, to guard against the occurrence of accidents arising from accelerated motion down the slope.

All the crossings, intersections, and abutments should be at right angles. This position obviously facilitates the turning from one road to another, and takes less time to cross right through. When two roads cross each other obliquely, or when one road abuts on another at unequal angles, turning or crossing can only be conveniently performed in one direction.

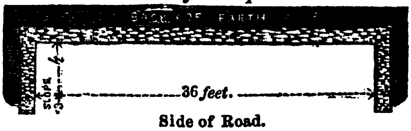
Many engineers of eminence recommend to pave the middle of the road, for the use of heavy traffic; while others, with more propriety, recommend to pave the sides. When the centre is paved, the man who attends the horse is in danger from the light carriages passing by quickly; but when the sides are paved, the waggoners are enabled to walk close to their horses, and take proper care of them, leaving the centre of the road for light carriages.

Depots.—Depots should be built on the side of the road, at the distance of about one quarter of a mile asunder, for the purpose of holding materials to repair it. It should be of some regular form, easily measured. Sir Henry Parnell recommends the back wall to be twelve yards long, and each of the sides two yards and a half at the bottom, and to slope at half a right angle to the top: the height should be one yard.

The dimensions here given would contain 24 cubic yards of road material; and therefore four of such depots, the number on a mile, would contain 96 cubic yards. These depots are not upon many of the Irish roads, which is an omission that often leaves a rut in the road for weeks. They are comparatively useless if placed at a greater distance asunder than a quarter of a mile; as to convey materials from them in a wheelbarrow, to a greater distance than one furlong, would be both tedious and expensive.

Specification for building Depots of stone masonry.—Two depots are to be built in such places as may be pointed out by the engineer or his assistant: they are to be built with stone and lime, upon a solid foundation. The dimensions are to be twelve yards in the clear at the back, with ends two yards and a half clear at the bottom, and to rise to one and a half yards at the top; the thickness of the work to be eighteen inches throughout for the height of three feet, and the work under that to be two feet thick. The top of the back and sides to be finished with Killiney granite, neatly hammer dressed. The back and ends of the depot to be secured outside, by making a mound of earth round them, two feet high, and two feet and a half thick at the base, rounded off at top, and well lined with sods. The floor of the depot to be flagged with Kilrush flags, neatly and evenly set: a proper drain to be made before the depot, thirteen yards long and nine inches in the square: the mound round the base to be planted with quicksets.

Plan of a Depot.



Side of Road.

Outlets.—Outlets are necessary to carry off the water from the side-channels of the road. They may be built of stone or brick; they are generally about one foot square. These outlets are sometimes made of tiles or iron pipes, when the water is to be conveyed from the side channel to the side drain. Particular care should be taken that an outlet should be placed at the end of every cutting, to carry off the water before it reaches the embankment.

Inlets.—The water from the side channels of a road should be conveyed into the cross-drains by side openings or inlets, ten inches by sixteen inches, built with stone masonry, and covered with good sound flags. Inlets are sometimes made along the channels, and covered with iron grates. In situations where water accumulates in large quantities during the time of floods, the grates should open on hinges, to allow the water to run off quickly.

ROAD-COVERINGS.

The best road-covering is that which lasts longest, and at the same time offers least resistance to the force of traction. To possess the one quality without the other, would leave the road still imperfect. Large blocks of unshapen stone, however durable, closely fixed together, without any regard to the formation of a smooth or even surface, would be ill calculated for carriages with any weight, or for unloaded carriages moving over it, with any degree of reasonable speed; and a road with a smooth and even surface, but composed of materials so weak and fragile as to yield, and crumble into dust, under the smallest pressure, breaking at once into ruts and cavities, serving as reservoirs to collect and retain water, is still more imperfect than the last. Therefore, to render a road useful, it must possess the two qualities above mentioned—smoothness of surface, and durability of materials. The bottom of the road must also be solid and unyielding, otherwise the road-covering will soon work its way into it, and force up the subsoil, which, mixing with the road materials, tends to accelerate their wear and tear. In wet weather, the subsoil, thus forced to the surface, prevents by its semi-fluidity, the union of the road materials into a solid mass; therefore the carriage wheels soon sink into it, furrowing it up into ruts, which render it impassable.

Some short time ago, the making and repairing of the public roads through Ireland were committed to persons without skill or science. An influential grand juror procured a presentment for making or repairing a road, which he was sure would enhance the value of his estate—the chief object he had in view. This job was given to such of his tenantry as owed most rent, by which they were enabled to clear off the arrears—the only consideration that guided him in his selection. The roads being thus committed to the care of such persons—persons without education, science, or skill—it is needless to say that, under such management, they must have been badly constructed, and kept in the worst possible condition.

The condition of the roads in England and Wales, at the time we allude to, was not much better; but the system of making, repairing, and general management has been so much improved of late years, by having received the particula rattention of men of scientific skill, and of the legislature, that the public now have little reason to complain, so far as regards the state of the public highways, the improvement in which having rendered travelling easy, pleasant, and expeditious. We recollect when it was considered beneath the notice of men of science and education to attend to this most useful department of engineering; and had not such men as Macadam and Telford, followed by Griffith, Nimmo, Edgeworth, and M'Neil, excited the attention of the public, by pointing out a better and a more scientific method of making and repairing roads, they might have remained in the same imperfect condition in which they had been, before these eminent persons had directed their attention to such works.

A short time before the introduction of mail coaches into Ireland, the construction of the public highways was invariably entrusted to persons totally unacquainted with even the lowest elements of science. Under the management of such persons, unassisted by the light of science, and uninstructed in art, the roads must have been in the worst possible condition. The introduction of mail coaches, however, soon changed the state of things for the better, effecting a complete revolution in the mode of travelling. By this new mode of conveyance, persons travelled over distances in a few hours, which, a short time before, required days to accomplish. A Cork merchant arrived in Dublin on the evening of the sixth or seventh day, laden with commissions from his neighbours, to execute which, with his own business, usually required a residence in the metropolis for two or three months, actively employed. Next year these friendly offices were executed by another of the principal traders, the small shopkeeper never daring to venture upon a journey so tedious and expensive. A similar practice was pursued by the wealthier classes of traders in Limerick, Tralee, Ennis, Galway, Sligo, and other distant towns in Ireland.

When the public roads connecting the principal cities and towns in Ireland with the capital, were in the condition here described, what must have been the state of the cross roads, made for the transmission of the agricultural produce of the country? Before carriage roads had been made through the remote districts of Kerry, it was the common practice to convey the butter in firkins, on men's backs, to the trackway, (for road it could not be called,) and from thence to the city of Cork in panniers or baskets, slung over a small poney's back, the journey requiring several days, and the quantity thus requiring such a vast expenditure of time and labour never exceeding two casks, weighing together one hundred and a half, or two hundred at most. The remote parts of Galway, Mayo, Clare, Donegal, and other counties far removed from good market towns, were in no better condition, so far as regarded the public roads. At this, not very remote period, no bridge crossed a streamlet, and many large rivers too were without any.

The absence of good roads, to facilitate general intercourse, is a barrier to national advancement in science, arts, manufactures, trade, commerce, agriculture, and every other thing calculated to increase the amount of human happiness. Without good roads, by which to bring manure from one place to another, the natural sterility of some soils would render them still unproductive, notwithstanding the care and attention bestowed on them by the farmer; whilst the spontaneous produce of the most luxuriant soils is considerably deteriorated by the difficulty and expense consequent upon the want of easy access to the market.

Many parts of Ireland abound with shell-sand, limestone, marl, sea-rack, and limestone gravel, but which lie useless (for want of roads) at short distances from localities which might be considerably enriched, and therefore enhanced in value, by constructing roads for the conveyance of manure. Without good roads, these natural treasures are like so many mines of gold, which are of no value till the precious metal is extracted and circulated through the land.

I have seen the truth of these observations verified in many parts of Ireland. I have invariably observed that as soon as a road is made through any remote district, a total change in appearance immediately follows. Sterility, unproductiveness, idleness, and the necessary attendant upon these—poverty, are soon succeeded by productive cultivation, industry, and their necessary consequences—comparative comfort and happiness. It is unnecessary to shew how trade, commerce, arts, manufactures, and the social condition of the nation generally, might be improved, by giving increased facility of communication and intercourse. A great deal has been done in this way, but very much yet remains to be accomplished.

Having given directions for conducting all the works connected with a public road, with the exception of the surface; we shall now call attention to that finishing part of the work. And first, we must observe, that men eminent for their skill and practical knowledge, have widely differed on this point; some contending that what is termed a pitched foundation, that is, a foundation composed of large stones, is necessary for the construction of a substantial and good road; while others maintain that no such pavement is essential. The one party say, "that you cannot make it non-elastic without the pitching;" the other, that "the pitching is so much expense needlessly incurred." For, say those who are averse to the pitching system, "if a more brittle material be laid upon one of a stubborn nature, and where there is not thickness enough of the inferior sort, of itself, or of its own weight, to support the loads it is subject to, that material, lying between two hard substances, must be pulverised. The heavy waggon-wheel above, and the hard pitching stone beneath, place the flint or gravel in a situation similar to the wheat between the grinding-stones. If, however, there be a thickness of materials upon the road, sufficient to preserve them from this effect, the weight of the flints themselves will form power enough to compose the road, without the solid assistance of the pitching stones. The plan of a pitched foundation could only have been resorted to where the funds so abounded as to allow of such an extravagant proceeding."

This argument, though apparently well founded, is contradicted by facts. If, indeed, but a single row of pebbles intervened between the carriage-wheels and the hard unyielding pitching stones, they might, no doubt, be ground; not, however, similar to the corn between the miller's grinding-stones. But a well made road does not consist of a single layer of small pebbles laid on hard pitching stones, but of many layers, composing a thick mass, which soon consolidates into a hard, compact, solid body, the surface only being subject to the crushing influence of the wheels, which only roll, but do not rub.

We recollect when it was the general practice, in making a new road, to spread the broken stones on the surface, which (the broken stones) of course yielding to every impression from above, soon exchanged places with the subsoil. This subsoil continually forcing its way through the broken stones, before they become sufficiently solid to prevent its protrusion, is, in wet weather, converted into mud, which soon renders the road unfit for carriages; and therefore new repairs become necessary. This must be the fate of every road made on the plan here described, except its natural foundation is composed of gravel, slate, shingle, or some unyielding rock, not easily displaced by any pressure from above.

Some are opposed to the practice of pitching, perhaps, from motives of economy; but though it may be somewhat more expensive in the first instance, it will in the end be found the cheapest; as when once completed, it seldom wants repairs; whereas a road made on the other plan requires frequent repairs. The manner in which the Holyhead road has withstood the constant travelling on it for so many years, proves, beyond a doubt, the superiority of the pitching system over any other ever practised.

Mr. Telford says, in his report, "that the great superiority which the Holyhead road evinced, was doubtless owing to the substantial foundation which had been prepared for it, previous to the upper stratum of broken stones being laid on it." This foundation is a regular close pavement of stones, carefully set by the hand, and varying in height from eight to six inches, to suit the curvature of the road. These stones are all set on edge, but with the flat one lowest, so that each shall rest perfectly firm. The interstices are then pinned with small stones, and care should be taken that no stone shall be broader than four or five inches, as the upper stratum of broken stones does not bind on them so well when they exceed that breadth." This is the plan described by Mr. Telford for making a road, and is now almost universally followed. The pavement, thus closely and solidly made, forms a sort of firm immovable barrier between the subsoil below and the upper stratum of broken stones. The pitching stones serve as so many drains, to receive the water that may percolate through the surface, and convey it to the next leading or cross drain, where it finally escapes.

Mr. Telford, in his report before the House of Commons, recommends the stones to be set by the hand, in the form of a close firm pavement. "The stones set in the middle of the road to be seven inches in depth; at nine feet from the centre, five inches; at twelve feet from the centre, four inches; and fifteen feet from the centre, three inches. They are to be set on their broadest edge, lengthways across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the irregularities of the upper part of the road pavement are to be broken off by the hammer, and all the interstices to be filled up with stone chips, firmly wedged or packed by hand with a light hammer, so that when the whole pavement is finished there shall be a convexity of four inches in the breadth of fifteen feet from the centre. The middle eighteen feet is to be coated with hard stones, to the depth of six inches; four of these six inches to be first put on, and worked in by carriages and horses, care to be taken to rake in the ruts, until the surface becomes firm and consolidated; after which, the remaining two inches are to be put on. The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the longest piece may pass through a ring of two inches in diameter. The paved spaces on each side of the eighteen middle feet are to be coated with broken stone or strong gravel, up to the foot-path, so as to make the whole convexity of the road six inches from the centre to the sides of it; and the whole is to be covered with a binding one inch and a half in thickness, of good gravel, free from clay or earth."

This has been the practice of Mr. Telford, whose name is a sufficient guarantee for its efficacy.

Road Materials.—Road makers are often led into very injurious mistakes, arising from their inability to choose the best sort of materials for the formation of the surface. It is false economy to use bad stone because it can be procured cheap, and near at hand, not considering that such material can never make a good road, and that frequent repairs would soon increase the expense far beyond the amount that would, at first, have been sufficient to make it of hard, strong, tough, and durable stone. Nothing is more common on some of the cross roads in the mountainous parts of Ireland than to see them altogether composed of what the country-people designate by the name of gravel, but what is no better than a sort of indurated clay or clay-shale, which, upon exposure to atmospheric influence, crumbles into dust. A mistake somewhat similar in kind, though much less in degree, is often committed on some of the English roads, near which flint abounds, and which, from its extreme hardness, one would suppose, ought to make a good road. But hardness is not the only quality essential in road materials. Flint, though very hard, is very easily ground into dust. Granite, though hard, is not the best road covering, as the felspar and quartz, especially if highly crystallized, are easily pulverised. Toughness and hardness are, therefore, necessary qualities, without which, no road can be substantial and durable; and what can be more expensive than constant repairs; or what can be more laborious to horses than to draw loads over a newly made or repaired road? The resistance offered by a rough surface, composed of fresh broken stones, to the force of traction, is very considerable, and, to overcome it, demands an immense expenditure of animal power; and when the road is made with bad stone, its surface will be almost always rough from the frequent repairs; constantly demanding an extra quantity of power, which might otherwise be effectively employed in moving the load. When the surface of a road well made, and composed of strong durable materials, is once smoothened down, it will remain in a good state for a long time, and will, comparatively, oppose but little resistance to the force of traction, by which the greater part of the horse-power is effectively employed, which is an advantage of no trifling import. This consideration alone ought to be sufficient to warrant an excess of expense, in the first instance, in the formation of a good permanent road, which will ultimately be found cheaper than one badly constructed, and of unsound materials, requiring frequent repairs. Hence the necessity of paying particular attention to the quality of the stone used as a road covering.

To give any thing like general instructions, by which a road maker might be enabled to make choice of the best description, for this purpose, is a task of some difficulty; as the mineralogical character of rocks comprehended under the same geological denomination, sometimes differ very widely. Perhaps the best advice we could give, in the way of instruction, is, to procure equal pieces of the stones to be tried, pound each separately, and that which required the greater amount of labour, under similar circumstances, is to be preferred.

Few countries afford greater facilities for the construction of good roads than Ireland, so far as regards its surface levels, its geological formation, and the abundance and cheapness of labour.

A great part of the north of Ireland abounds in basalt and greenstone rocks, which make excellent roads. The general character of the interior of the country is, with few exceptions, limestone, which, from its cementing property, is a very excellent road material; but if it be very friable, it is not good. Some parts of the elevated coasts is composed of grawackey, which, in the absence of better, makes a tolerable road, when kept dry: it is, however, weak, and does not bear much pressure, yielding under a small weight, and wearing very fast. Granite, which is found in many parts of the country, is far superior to any of the schistus rocks; the darker the colour, the better it is adapted for roads. Syenite and porpheritic rocks are good road materials. The Kilkenny granite is, perhaps, the best in the kingdom for a road covering. Hornblende, if found in sufficient quantities, ought to be excellent as a road material, as it possesses two very essential qualities—hardness and toughness. Limestone gravel, when screened and cleaned, makes a good covering; but gravel of any other sort is not to be depended on. Pit gravel, containing fragments of red sandstone, with harder fragments of different sorts of other rocks intermixed, does not answer well—it being essential to have all the component parts consist of homogeneous materials. When the road surface is a heterogeneous mass of materials, some hard and some soft, the latter sort soon suffer from the pressure of the former, when both are subjected to heavy weights, and to the grinding influence of the carriage wheels.

When pit gravel is used, the common practice on the cross roads, is to cart large quantities on the road, sometimes containing much clay, and of every size—large, small, round, and angular; the larger stones are broken here and there, just as they may happen to lie, and the entire is then spread over the surface, which, from such management, can never be made of equal strength or durability. Indeed in some cases, the larger stones are broken after they have been spread out. Before carting the gravel, it should be sifted, the large stones which remain broken to the proper dimensions, say two inches; then the largest size should be laid on first over the pitching, and when the first coat becomes a little settled, the next size may be laid on, and ultimately the smallest sized gravel, which was the residue of the first sifting, might be used as a binding: this will also answer for the pathways. By sifting the gravel through a close sieve first, the smallest size will be separated from the clay, which is so injurious to the road, being converted into mud by the first shower of rain that falls. This sorting of material is of great use in making a road; as when stones of various sizes are put on promiscuously, after a little time, when the surface becomes a little worn, the larger stones will be seen protruding through the surface, which should be broken before another coat is laid on for repairs.

A difference of opinion exists with regard to the comparative size of materials possessing different degrees of hardness. There is not, however, a doubt but that the tougher the stone, the smaller the size into which it should be broken. The quantity of broken stone to be put on at one time, is a point of considerable importance in road making. It is a mistake too often committed, to lay on at once several inches of stone.

This is often the practice in repairing roads too—a large quantity is laid on, and very often without opening the surface to receive them. When too great a quantity is laid on at once, it takes a long time to consolidate, and friction has a very destructive effect as regards the wear and tear of the materials, on account of the facility with which they can move amongst one another, by which they are rounded, and therefore rendered more unsteady, and less capable of forming that union absolutely necessary to form a solid and smooth road.

It is an equally injurious practice to put on too thin a coat. In this case, the wheel will have little or no difficulty in introducing itself between the stones, which offer little or no lateral resistance to the force which separates them. In repairing a road, some writers recommend never to put on more than one stone's thickness, which, for the above reason, is not sufficient—two stones' thickness at least, besides gravel binding, should be put on. If the gravel binding be sufficiently strong, then one stone's thickness may answer very well. When the substance of a road requires to be increased for the purpose of raising its surface, as well as otherwise improving it, the process should be carried on gradually. One thin coat should first be put on, and after giving it some time to bind a little, a second thin coat should be laid on, which, after being consolidated, should be followed by another, and thus the process may be continued till the surface is brought to the required height. This mode of proceeding will save a quantity of material, and produce a road superior in every respect to one which is raised to the same height by one coat at once, into which the carriage wheels can easily sink, forming a deep cut, which is sunk deeper by the next carriage, which no doubt will follow in the same track; and thus every succeeding carriage sinking deeper and deeper, the road soon becomes impassable, rendering fresh repairs necessary.

Whether the coating of the road be put on thick or thin, the tracks of the carriage wheels should be raked in, till the road shall have acquired sufficient compactness to render the use of the rake any longer unnecessary. When one side of a road becomes smooth, no carriage would willingly pass over the rough side; therefore, to make both sides available, travelling should be interrupted on the smooth side, by placing obstacles on it, which would necessarily convert the rough side into a thoroughfare. Then when both sides are brought to the same state, these obstructions should be removed.

In repairing an old road, containing a large quantity of stones of dimensions too ample for the purpose of a road, so much so as to render travelling dangerous, the common practice some time ago was to fill the neighbouring ruts with equally large rock, filling the crevices with any stuff near at hand.

In some instances a road may be remodelled and repaired, without much additional material, by lifting these huge stones and breaking them to the proper size, by which the expense of carting fresh stones from a considerable distance will be saved, and the road improved both in shape and substance. The cross-section of a road is another point that demands attention. The fall from the centre towards the sides must in every case be sufficient to carry off the water, otherwise it will lodge on the road, create mud, and accelerate the wear and tear of the materials. The slope towards the sides should always be more abrupt than that in the direction of the road, as otherwise the water, in heavy rains, would soon wear out furrows parallel to the axis of the road, which would render new repairs necessary. The convexity of the cross section of a road should never be more than is sufficient to carry off the water, as too abrupt a fall towards the sides would render the central part of the road the only thoroughfare, it being dangerous for carriages to travel on the sides, lest they should overturn. Travelling being confined to the centre of the road, that part would soon be cut into ruts requiring the professional services of the road maker. Hence the necessity of paying due attention to the cross section of the road.

In putting on fresh materials, the old surface should be loosened with a pick-axe, to the depth of about an inch, in order that the fresh covering may incorporate with the old road, and both form one mass. Without loosening the hard surface of the old road, the fresh coat would either be ground under the wheels, or shift its place to the right or left, leaving the old surface bare.

When a new road is finished or an old road repaired, it is to be supposed that it no longer requires attention.

Considerable expense is often incurred by neglecting to pay proper attention to a newly made or repaired road. All the ruts made by the wheels should instantly be filled up, not by a fresh supply of broken stones, but by raking in the stones which had been displaced. When a road is brought to a sufficient state of perfection by the various processes which we have described, the next point that demands attention is, to keep the road free from mud or dirt of any kind. When the mud is suffered to remain long on the road, it prevents the free escape of the water, and renders the draught heavy and difficult, demanding an injurious amount of animal power. Nothing is so injurious to a road as to allow water to rest on it for any time. When the water does not readily escape, it soaks into the road, loosens and softens the materials, and renders travelling unpleasant and difficult. Moreover, if a hard frost ensued, its effects upon the road, thus charged with water, would be very destructive. It is therefore unnecessary to impress upon the road engineer the necessity of attending to every particular tending to keep the road perfectly dry. Besides due attention to a proper system of drainage, and the necessary convexity of the road, every object intercepting the drying influence of the sun and air should be removed. All the fences along the road should be kept low, by keeping the hedges properly trimmed. This should be attended to in an especial manner, as a road with high walls or lofty hedges is very difficult to be kept in good condition, being precluded from the sun and atmosphere. The shameful neglect of this, in almost every part of Ireland, proves how insensible the people are to its good effects, and how little they appreciate the benefits resulting from so very easy a task. When a hedge is trimmed, the object is to make it grow and look better, but never to improve the state of the road. In making the foot-paths, particular care must be taken to protect them by a curbstone, or by a sod with the grass side up, permanently fixed along their margin. The deep side drains required to carry off the water to the natural courses, should invariably be made on the field side, making a small parapet or separating fence on the outside of the foot-path, of the stuff raised from the cutting. Frequent communications should be made under the foot-path, and cross-wise, for the water to escape from the small side channels running between the foot-path and road.

By separating the side drains from the road, travelling is rendered more secure, and the general appearance neater. Large side drains, not thus separated by a fence, are both dangerous and unsightly, and often prove fatal to men and animals in the night, and during and after a fall of snow. These fences should never be so high as to prevent the road from receiving the full benefit of the sun and air. A very low fence, with a deep ditch on the field side, will effect a perfect drainage, and prevent trespass of cattle. By leaving a road thus exposed, especially on the sunny side, a saving of at least twenty per cent. will be effected in subsequent repairs. It is a practice very injurious to roads, but one very common in Ireland, to plant trees quite close to them: when the direction is north and south, a plantation on either side is not so injurious, as the road in this position must experience the beneficial influence of the sun every day in the year; but when a road runs east and west, a plantation on the south side must necessarily deprive it of the benefit of the sun's rays during the winter months of the year.

When the road metal is of a soft description, the convexity of the cross section must be increased, as water lodging on such materials would be very destructive. The fall on most roads, from the centre to the sides, is too great; than which nothing can be more injurious to the road itself, or more inconvenient to carriages: as when it crowns too much, every one avoids the sides, and therefore the middle is soon cut into three furrows by the horses and wheels. The resistance is very much increased by having the load unequally distributed on the wheels; and as the convexity increases, the weight is thrown more and more on one wheel, and taken off the other. Quick travelling on a very convex road is very dangerous, especially when the carriage is high and top heavy. When the road is tolerably level, every part of it is travelled on, by which an equal wear and tear takes place, and an equal distribution of the load on the wheels diminishes the resistance, and renders quick travelling more secure. Hence the necessity of avoiding too great a rise in the middle. The ascents and descents, in the direction of the road, should be as little as the contour of the country will admit of, consistently with the economy of expenditure. When it becomes necessary to make a road in side cutting; that is, to make a road by the side of a hill, in such a way as that what is taken from the upper side may serve to form the embankment on the lower side, the best way to proceed is, first, to cut off the natural sod, which would be covered by the base of the embankment, and lay it aside; then the earth is wheeled to the outside of the embankment, which is always kept comparatively high, till all is brought to the required height. By this process the work is kept from slipping, which it must do if the earth is wheeled from the upper side and thrown promiscuously on the lower, and then left to settle. When one part of a road is excavated, and the earth removed to a lower part, for the purpose of bringing the surface to the required height or level, the natural surface of the base of the embankment is laid aside, as before, and the earth carted or wheeled to form the outsides, which are raised to the required height, leaving a valley in the centre to be filled up last. The outside slope is then lined with the reserved sods, which, taking root, form a good natural protection against the effects of rain. When the earth-work is executed in this manner, the tendency of the mass is towards the centre, by which the liability to slip is a good deal diminished.

When a road is much exposed to traffic, its surface requires to be renewed at least once a year. The wear and tear of a road is very seldom, if ever, uniform throughout, being most generally partial. When this is the case, the repairs might be effected by filling up the hollows with road metal. We would however observe, that partial repairs, though allowable at a distance from towns, from motives of economy, are by no means to be recommended, as a road thus partially repaired never possesses equal firmness throughout, which a thorough repair always insures. The best season of the year for doing the repairs of a road is about the month of October and November, before the frost and snow set in. But this being generally a very busy season, the summer months might be profitably employed in the improvement of the highways. In this season the necessary materials are more easily transported from one place to another, much more work done in a day, and the labour of men and horses procured in greater abundance.

The scraping of the road is another duty which demands the particular attention of him who has the care of it. When mud is left for any time on a road, it prevents the water from flowing off, than which nothing could be more injurious. Persons bordering on the road would be repaid by employing the scrapings of the road as a manure, for which it answers well. When the road covering is limestone, the scrapings make an excellent manure; ground stone, almost of any kind, mixed with the refuse of horses, particles of iron from wheels and horse-shoes, answers well for many soils, especially for heavy clay grounds.

In a district where no stone can be had, but in which gravel abounds, from motives of economy this is employed in preference to the former. After having prepared the foundation of the road in the manner recommended before, four inches of the strongest description should be first laid on; and to give it some degree of firmness, carriages should be allowed to roll over it for some time, due care being taken to fill in the ruts made by the wheels: then another coat of four inches deep should be put on, which should get sufficient time to consolidate before it received the next coat of equal depth; and in this manner the process should be repeated till the road is from sixteen to twenty inches thick in the middle, and from ten to twelve inches thick on the sides, according as the material may be found strong or weak. The middle fifteen feet should receive the strongest description, reserving the weaker sort for the sides.

Every road should be supplied with mile-stones, which are both convenient and agreeable to the traveller, saving him the trouble of asking questions respecting distances as he proceeds on his journey, and receiving answers which often tend to mislead him. Mile-stones enable the coachman to keep regularly to his time, which he would find difficult without them: they are also convenient and useful to the road surveyor, in laying out and measuring his work.

When a new line of road is determined on, there is a great variety of circumstances to be particularly attended to, both for the information of the part of the public interested in the road, and of those who superintend its construction.

Drawings should be made, showing the section and plan of the natural surface of the line, with the longitudinal inclination of the proposed surface. The road-surveyor should also be supplied with drawings, exhibiting the slopes of the cuttings and embankments, the form of the bed of the road and foot-path, also the number of coats to be put on, with the thickness of each; and finally, drawings should be made of all the intended bridges, culverts, drains, fences, depots for road material, &c. along the line. All these should be accompanied by a specification, explaining in detail the precise method of executing every part of the work to be done. These supply sufficient data to make out an estimate of all the expenses to be incurred.

The following is an estimate for making a part of a new road:

To removing 1765 cub. yds. of earth, at 9*d*	£291	3	9
To 1767 lineal yds. road making, at 15*s* 6*d*	1369	8	6
To 1767 lineal yards of fencing, at 5*s*	441	15	0
To drains	40	0	0
To forming	80	0	0
To sodding	80	0	0
To depots	38	0	0
To bridge	560	0	0
To side roads	20	0	0
To gates	5	0	0
To 4760 cubic yds. of extra embankment, at 6*d*.	119	0	0
To extra carriage of stone	60	0	0
	£3104	7	3

The annexed plate contains a plan and section of a road, AB being the plan of the line, with all its turnings and windings, and A′ B′ the section with all its slopes. On the plan and section should be represented the natural surface of the ground, the latter shewing besides the surface of the proposed road. The figures at top shew the rise and fall in each particular length, and the figures written vertically shew the distance of each respective point in the proposed line, from the horizontal datum line A′ B′. The figures written horizontally under the section shew the distance of each respective point, from the commencement of the line at A′. In this part of the road the excavations are not equal to the embankments. This circumstance is due altogether to the nature of the substratum. Where the substratum is found to be so hard as to demand too great an amount of labour and expense, the cutting is not carried farther than is necessary to bring the surface within the limits prescribed by the angle of friction. The points *a*, *b*, and *c* would have been cut lower, if the difficulty and expense of cutting through the rocks at these points had not prevented it.

A Road made wholly of Broken Stone.—In cross roads, where the traffic is not very considerable, the road may be wholly made of broken stone, which will answer very well. A level bed is first formed on the natural soil, and due provision made for drainage and fencing, as before directed: then successive layers of broken stone may be laid on, to the depth of twelve inches in the central parts, and six inches on the sides, giving sufficient time for each layer to consolidate before another is put on. This is an old plan recommended by men of eminence as road makers: when the traffic is considerable, it is found not to answer so well as the pitched road, being always too weak, and requiring large outlays for some years after its construction. A road made without pitching the bottom always yields under a heavy load, by which additional labour is imposed on the horses, being always obliged to draw up an inclined plane, though the road be ever so even.

Frost is found to act with much more injurious effect on a road made wholly of broken stone, than upon one with a pitched foundation; as in the former case, the water must either rest among the working materials of the road, or on the clay under the road materials, till drawn off by evaporation; and should a hard frost come on while the road is in this saturated state, its effects must be very injurious, the water being expanded by the operation of freezing, with a force so great as to tare up and separate all the materials composing the surface. The materials being thus loosened and separated, yield to the smallest pressure when a thaw takes place, by which the whole surface is converted into ruts, requiring fresh repairs; but when the foundation of the road is paved, the water escapes through the crevices, and the frost being unable to penetrate through the pavement, does very little injury.

Having given the necessary directions for laying out, constructing, and repairing roads, it may be interesting to offer some account of the introduction of the improved system here pointed out. The attempts to improve the principal thoroughfares of England, may be dated from the beginning of the eighteenth century.

It was only about that period that persons began to feel the necessity of improving the highways, for the purpose of giving greater facilities of intercourse, by increasing the speed and shortening the time required to travel from one point to another. In order to effect these objects, various acts of parliament, termed turnpike acts, were passed for different districts in the neighbourhood of London, not however without a strong remonstrance from all the surrounding counties, against the extension of these turn-pike roads into the more distant parts of the kingdom; alleging as a reason, that these remote districts, from the cheapness of labour, would be able to sell their corn in the London markets at a lower rate than themselves, which, as they believed, would have the effect of reducing their rent-rolls, and ruining their cultivation; but which, however, had a contrary effect, as might naturally be expected from a free and expeditious interchange of commodities. Notwithstanding these remonstrances, which prove the blind and contracted views of the times, as compared with the rapid march of improvement in our own day, the turn-pike roads were extended into the remoter counties of England. But though the improvement of the roads received more attention at this time from the legislature than at any former period, the proper system of making a good road remained yet to be learned. Previous to this time, the roads were almost impassable in winter, and the improvement introduced for some time after, consisted merely in making the paths somewhat more level than formerly, and of filling up the ruts and holes with stones gathered from the adjoining field. In those days no pains were taken to break or sort the stones; all were thrown into the hole or rut, large and small, without regard to arrangement or evenness of surface, the only object sought being to prevent horses from sinking, paying little regard to the jolting of the carriages, which of course must have suffered severely, though ever so lightly laden.

Public attention having been once excited, every successive attempt at improvement must have been attended with more or less success. Engineers of skill began to consider the subject, and men of education and property, sensible of the great evil of imperfect roads, turned all their energies to the improvement of the highways; and foremost among these may be mentioned Mr. Macadam, whose name is now associated with every good road in the united kingdom. What led Mr. Macadam to turn his attention to the mechanical principles involved in the construction of roads, was his having been appointed one of the trustees on some roads in Ayrshire; but having been otherwise engaged for many years, it was only in 1815, when he was on the borders of sixty, that he began to devote his whole mind to the business of road-making. It was he that first recommended to break the stones in the manner before described; but recommended to place them on the soil without any paving or pitching—the only particular in which we differ with him. To him are all the towns in Great Britain and Ireland, that have followed his plan, indebted for the substitution of broken stones on the streets, for the large blocks with which they used previously to be paved. Any one driving through our back streets which retain the old pavement, may easily appreciate the pleasure of driving through any of our Macadamised streets.

The expenditure of animal power, the wear and tear of vehicles, and the disagreeable jolting motion experienced on the old rough pavement, are considerably diminished by the Macadamised plan, which has rendered travelling easy and pleasant.

Mr. Telford improved upon the Macadamised plan of making new roads, by the introduction of what he calls pitching, which is now very generally practised by the most approved road makers.

RAIL-ROADS.

The government of every country into which railroads are introduced, should have some controlling power, both in the laying out and subsequent management of the lines, whether they are actually formed by the state or by private individuals. We do not mean to point out here the extent of power that ought to be exercised by the state, in the management of railways constructed with private capital; but the conflicting interests of private companies having no unity of purpose except to make as much profit upon their individual outlay as they can, and the want of unity of plan so apparent in the English railways, most of which have been designed in short lines, prove how necessary it is to have them under the controlling power of the state. In offering this opinion, we are not to be understood as wishing by any means to check private speculation or commercial enterprise, being well aware that the rapid progress of the railway system in England, though by no means unexceptionable, is mainly due to the stimulating agency of both.

The evils inseparable from a system of railways not under the control of a duly qualified board, with sufficient power derived from the legislature, are felt by the company as well as by the public.

The share of the evil sustained by private companies may be estimated by a reference to four lines of railway with which the public are familar; namely, those issuing from London towards Liverpool and Manchester, and that connecting Dublin with Kingstown, and the one now in progress of construction from Dublin Drogheda.

The enormous, and in many instances unreasonable exactions of landed proprietors and others, not limited by any scale in their demand for compensation, except that which is the measure of their own individual avarice, and the vexatious expenditure of capital in obtaining Acts of Parliament; are evils which might be obviated by a properly constituted board, appointed by the government of the country, with power to arbitrate between disputing parties relative to compensation, and to obtain, for approved lines, Acts of Parliament free of expense. We have heard of some cases in which landlords actually demanded and received fifty times the amount of their real loss, and in cases too where the road served to enhance rather than deteriorate the value of the property. Such selfish conduct is but ill calculated to advance the state of the country. We are happy, however, to have it in our power to state, that there are some noble exceptions to be found among the landed proprietors of Ireland, whose generous conduct in offering to make no demand for the lands on their respective estates occupied by, and for the use of, any line of rail-way that might pass through their properties, proves what a lively interest they feel in the advancement of any measure having for its object the improvement of their native country. In all cases where a projected line has been opposed, the parliamentary expenses to the company have amounted to £1000 per mile, and there are cases in which they have amounted to £2000 per mile. The restraint under which private companies are by the law, as relating to deviations and time especially, often obliges them to do every thing connected with the line in too great a hurry, which often occasions a bad selection and much extra expense. The evils of the present system, which places our public highways under the control of private companies, are serious and manifold. As monopolists with vested rights, every company may charge what they please for the transmission of goods and passengers, and have it in their power to inconvenience the public in various ways. By virtue of their vested interests, these corporations become undisputed masters of the public roads, uncontrolled by the state; and as such possession bestows a power which may be exercised either for or against the state, it would therefore be a wise policy in the government to retain such a share of controlling power as would make them the natural guardians of the Queen's highways.

There is another point of paramount importance to the public, to which the attention of parliament has been lately directed. The frightful amount of human life lost in consequence of accidents, which have so frequently occurred of late on the railways in England, could no longer be witnessed by the legislature, without at least making an effort to check an evil of such vast magnitude; accordingly, a bill has been lately passed for the better regulation of railways, which, it is hoped, will obviate most of the objections, as regards accidents, to the old system, and have the effect of rendering travelling more secure, and restoring public confidence, which, from the frequency of accidents, had been considerably shaken. There are, however, clauses in this bill which are objectionable, and time will point out the necessity of amending them. The bill, indeed, as a whole, is a good one when viewed abstractedly, but when its practical operations are examined, it will be found to contain many things that are injurious. Were it not inconsistent with our plan to discuss the subject of this bill in detail, we might point out some parts of it which are of no positive good to any party. We may however be permitted to mention, that much mischief might result from unlimited power being given to the Inspector-General, who, by possibility, might be a weak-minded and ignorant man; but from whose decision there is no appeal. We think that a greater degree of responsibility might have been thrown upon the constructing engineer and directors, which no doubt would have the effect of making them more vigilant and cautious, both in the discharge of their respective duties, and the selection of subordinate officers.

There is nothing connected with the construction of rail-roads that requires more judgment and caution, on the part of the engineer, than in the selection of the best line to connect two given points. In selecting a line of road, a variety of circumstances is to be considered. One line may present numerous favourable as well as unfavourable circumstances, and in comparing this with another, connecting the same extreme points, which likewise presents a variety of favourable and unfavourable circumstances, the preference must be given to that which has the greater amount of favourable circumstances, balancing all the points for and against each, and comparing the final results. This enquiry is one of great difficulty, often requiring the expenditure of much time, labour, and capital; and always considerable scientific ability and discriminating judgment. In making this enquiry, it would be well perhaps to compare the expense of making each line, then the probable traffic on each, and lastly, the time it would take, by the same quantity of steam power, to perform the journey by the respective lines. To facilitate the enquiry, those items which are equal in each may be left out, comparing only those which are unequal, and from them striking a final balance. For instance, if the expense of making two lines of road were found to be equal, then the probable traffic upon each, and the time required to perform the respective journeys, by the same amount of steam power, should be compared. The probable expense of keeping each line in repair, after having been completed, is another item that should be taken into account.

The probable wear and tear of machinery, and the safety of travelling on each line, all other things being equal, should be carefully considered.

In comparing the traffic on the competing lines, what is meant is the amount received for the transmission of goods and passengers by each.

With mercantile men and others, with whom a saving of time is an object, quick travelling is of vast importance; therefore, time is an element that should be taken into account. High embankments, deep cuttings, abrupt curves, long tunnelling, elevated viaducts, and expensive bridges should be avoided if possible, as they add materially to the cost of construction, and increase the liability to accidents very considerably. Circuitous lines, to pass through towns of no importance, are not always to be preferred. A more direct course is recommended, except in cases where a deviation from it is warranted by an increased amount of traffic, afforded by the intermediate towns on the circuitous line.

In connecting two distant points, a circuitous line to serve an intermediate town, though of importance, may not at all times be the best; it being in many cases advisable to connect the intermediate town to the main line by a short branch road.

Among the maxims in railway construction, are—that the whole line may be traversed by the same engines: that when two lines are equal in every other respect, that is to be preferred which passes through the most populous and the richest country in minerals, soil, and agriculture: and that it should combine the greatest effect, produced in the shortest time, and the greatest amount of public convenience, at the least possible expense. The only difficulty that presents itself in the construction of a railway, is the fulfilment of all those laws or maxims which we have pointed out as essential. The mechanical works of a rail-road may be executed by a man of ordinary skill, destitute of science and literature; while the laying of it out to the best advantage requires a knowledge of both, besides an extensive and intimate acquaintance with the statistics, laws, &c. relating to it.

When the mean value of the gradients throughout a line of railway is required, the value of each particular gradient, with its proper sign, must be multiplied by its length; then the difference between the sum of all the positive products, and that of all the negative ones, being divided by the length of the whole line, including all the levels in the same measure, will give the mean value of the gradients, reckoning the ascents positive, and the descents negative. Hence may be derived a method of comparing the effects of two lines: for, if the length of one line, multiplied by its force of traction, be equal to the product arising from the multiplication of the length of another line by its force of traction, equal tonnage would be transported along each line in equal times, by locomotive engines of equal power. This is the best rule that could be given for finding the relative effective powers of two lines of railway, and determining which ought to be chosen.

Various experiments have been made, from time to time, to ascertain the effects of slopes. To do this, it is necessary to ascertain the amount of tractive force necessary to propel one ton on a horizontal line of railway properly constructed. This is generally assumed at 8½ ℔ per ton, being the mean result of repeated experiments. Now, 8½ ℔, the amount of traction, being the $\frac{1}{264}$th part of 2240 ℔, the weight propelled, it follows that the traction on a level railway is the $\frac{1}{264}$th part of the load drawn.

But by mechanics, the weight moved, upon an inclined plane, is to the power, as the length of the plane is to the height thereof. Hence it follows that if a train be drawn up an inclined plane, rising 1 in 264, an addition of 8½ ℔ to the traction on a level road will be required to draw one ton (2240 ℔) up such an inclined plane; that is, twice the force will be required to draw a ton weight up an inclined plane, rising 1 in 264, that would be sufficient to draw the same load along a horizontal plane, the velocities on both planes being the same. Again, if the rise be 1 in 1000, an additional tractive force of 2.24℔ per ton will be required to ascend such a plane; that is, a tractive force of 10.74℔ per ton will be sufficient to draw a load up the inclined plane, with the same velocity as on a level plane which only required a tractive force of 8½℔ per ton.

Mr. Tredgold made various calculations on the expense of ascending and descending inclined planes, as compared with the cost of cutting them down to a level, and the result made him think it better to follow the undulations of the surface. He says, "if a few examples (of comparative expense) be added, it will assist in removing those extravagant notions of cuttings and embankments, by which the capital of the country is wasted in unprofitable speculations."

In ascending from a lower point to a higher, a uniform inclination should be had, if possible; but if the expense of making the ascent uniform be too great, the entire is to be made out in stages, recollecting the maxim laid down in the treatise on common roads, namely, that after having attained any elevation, the line does not, if possible, descend again.

Where a local difficulty occurs, it is always better to overcome it, at the expense of a large outlay, so as to make the work substantial and durable, than to run the risk of entailing future liability by a small outlay in the first instance.

The greatest difficulty the engineer has to contend with, is the comparison of the respective advantages of different lines of railway.

M. Navier says "that the elements of comparison of different lines of railway may be divided into two heads: first, the establishment of a very rapid mode of transport—a consideration which should give a preference to the shortest lines, the velocity being supposed to be the same in all: second, the increase of wealth which may result from the establishment of a line of railway." He further states, that diminution in the cost of transport is the principal circumstance to be considered. "We should even say that the rate of reduction which is obtained upon the actual cost of transport, by the establishment of a new communication, is almost the only circumstance which should be thought of."

M. Navier, in his work, throws out many useful hints on the means of comparing the relative advantages of railways. This has been translated by Mr. M'Neil, a gentleman in every way eminently qualified to execute the task.

It may be useful to the young engineer to know how to determine the amount of power requisite to draw a given train over a given railway. M. Navier takes the friction per ton at 11lb, therefore $\frac{11}{2240}=\frac{1}{200}$. Then he says, "we conclude from this, that in order to transport, with any velocity whatever, constant or variable, a weight W to a distance represented by a on a horizontal line, it is necessary to employ the power represented by $\frac{W}{200}\times a$; that is to say, the power necessary to raise the weight to the height $\frac{a}{200}$." The friction on different lines and in different carriages being variable quantities, (being however in every case within small limits,) the above formula does not answer for every case that may arise. Let F represent the friction per ton; then $\frac{F}{2240}\times W\times a$ will express the power.

To determine the Angle of Friction.—The angle of friction denotes that slope or inclination of a plane on which the force of gravity, parallel to the plane, is equal to the retarding force of friction: from which it follows, that if a body be placed on such a plane at rest, it will continue to sustain itself; or if the body be put in motion, that motion will continue uniform.

If we make W to represent the weight, l the length of the plane, and h its height; then, by Article 119, Wood's Mechanics, the force necessary to sustain the body on the plane, disregarding friction, is $\frac{h}{l}$ W. Now, when this friction is equal to that which expresses the ratio between the friction of a body and its weight, it is called the angle of friction.

If the friction be equal to the above sustaining power, it is evident the angle of friction will be represented by $\frac{h}{l}$ W, which expresses also the amount of friction sufficient to keep a body at rest on a plane, the moving force being that of gravity: that is, $F = \frac{h}{l} W$, where F represents the friction, and h, l, and W the height, length, and weight, respectively.

Numerous experiments have been made, with a view to ascertain the angle of friction on rail-roads, and from the results of the greater number of them, it would appear that the angle varies between 1 perpendicular to 260 in length, and 1 to 280; or from a rise of 18.8 to 20.3 feet nearly for one mile in length. The resistance of the air to the motion of the carriages down an inclined plane, as well as that arising from friction, is here included.

Some attempts have been made to show that a railway formed in a series of undulations would be preferable to one perfectly level: but this doctrine has made very few converts. The persons that would fain to impose such a doctrine, argue that because the power of gravity might be used to aid in the descents, and that of acquired momentum in the ascents, the amount of artificial power required for moving carriages upon the road is considerably diminished.

The danger attending undulating railways, especially when the slopes exceed a certain limit, will induce many engineers to avoid them as much as possible, consistently with due regard to economy.

It is affirmed by many eminent engineers, that an elevation of twenty feet in a mile, requires an additional exertion of power equal to that on one mile of a level rail-road: if this be the case, it follows that the same power which would move a given load over one mile of railway, rising 1 in 264, or twenty feet in the whole, would move the same load over two miles of level road. A correct knowledge of this fact is of great practical importance, as showing how far it may be advisable to deviate from a direct course, in order to avoid a given elevation.

When it becomes necessary to conduct a railway over a considerable elevation, it is a matter of importance to ascertain whether it is better to distribute the rise and fall equally throughout the line, or concentrate them in a few steep planes, which are to be ascended by means of additional power, the rest of the line being comparatively level. On the Manchester and Liverpool railways there is no gradient exceeding 1 in 849, with the exception of two inclined planes of about one mile and a half each, inclining 1 in 98, and 1 in 96. At these planes the train is made to ascend by means of an additional locomotive engine.

The Great Western railway has no steeper gradient than 1 in about 812, in a distance of 117½ miles, excepting two inclined planes of 1 in 100. On the London and Birmingham railway, the ordinary gradient is 1 in 330, except on the extension from Camden Town to Euston-square. The ordinary gradients on the Brighton, South-Eastern, South-Western, and several other lines, is 1 in 264.

It is the general opinion of engineers, that a certain degree of similarity in the gradients is very essential to the economical working of a railway by steam power. Should the road present an inclination so steep, that the ordinary power, by a reduction of speed, could not surmount it; then additional power must be employed, or the engine must run over other parts of the road without its maximum load; by which, of course, an unnecessary expense is incurred. But as long as this inconvenience is avoided, it is the opinion of men high in public estimation, that the degree of inclination on a railway, with equal traffic in both directions, is of little consequence, the assistance of gravity in the descent being nearly equal to the retarding force in ascending. The amount of power lost in ascending being somewhat equal to what is gained in descending, brings the entire amount of power required to pass over, in both directions, the whole distance, equal to what is required to pass over an equal distance on a perfectly level road.

Dr. Lardner brought this under the test of a series of experiments, the results of which seem to indicate a compensating effect, and that, too, in slopes of greater steepness than most persons would suppose to be capable of producing such results. We give them as recorded by the learned Doctor, without recommending them as fundamental principles, to be employed without further enquiry or more experiments. A limited number of experiments, however well conducted, should be received with caution; but the result of these experiments should stimulate others to make further enquiry.

"In July 1839, the Hecla engine, with twelve carriages, making a gross weight of eighty tons, the engine being included, was run from Liverpool to Birmingham, and back in the same day, by which means the same train, under as nearly as possible the same circumstances, had to ascend and descend every plane on this line, a length of about ninety-five miles. The time of passing each quarter of a mile was carefully observed, so as to obtain the speed on every portion of the road."

The following table, taken from Doctor Lardner's work on the steam engine, exhibits the results of his experiments on gradients varying from level to 1 in 177, or nearly thirty feet per mile:

Gradients.	Speed in ascending.	Speed in descending.	Mean Speed.
One in	Miles per hour.	Miles per hour.	Miles per hour.
177	22.25	41.32	31.78
265	24.87	39.13	32.00
330	25.26	37.07	31.16
400	26.87	36.75	31.81
532	27.35	34.30	30.82
590	27.37	33.16	30.21
650	29.03	32.58	30.80
Level	..	..	30.93

By comparing the numbers in the columns above, we see that although the gradient of 1 in 177 diminished the speed from 30.93 miles per hour, which is the velocity on a level, to 22.25 miles per hour, in the ascent, the deficiency was more than compensated for in descending the same plane, the velocity per hour in the descent being 41.32 miles; making the mean velocity on this slope in both directions 31.78, which exceeds the speed on the level by .85 parts of a mile per hour. Comparing the mean velocities per hour, in both directions, on the different gradients, with the speed per hour on the perfect level, a very useful and remarkable fact may be learned; namely, that a line of railway, with gradients varying from twenty to thirty feet per mile, may be worked in both directions by the same expenditure of power as a dead level; and this fact, if substantiated by more experiments, will be the means of saving many millions in the construction of future railways, by adopting steeper gradients than have been hitherto considered advisable.

Mr. Macneil, acting upon this principle, has altered the original slopes, as laid down by the engineer who preceded him, on the Dublin and Drogheda railway, by which he has effected a great saving to the company engaged in that work.

Dr. Lardner does not attribute the whole of the compensating effect here produced to the agency of gravity and momentum, a part being due to the diminished resistance of the air to the passing of the train up the ascent, owing to its reduced velocity.

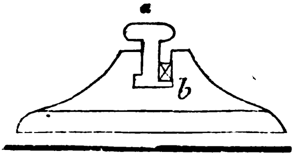
The resistance of the atmosphere is another upon which the Doctor experimented, but his results do not satisfy: he attributes much more to the agency of this resisting medium, in diminishing the speed of carriages moving on a railway, than is due to it according to the experience of many others who had equal opportunities. We recollect his having assigned a maximum limit to the speed of carriages, which is considerably exceeded on the different English railways—a fact that proves we are still in need of more experiments upon this point. While any doubt remains on these two points—inclinations and atmospheric resistance—it were well if so competent a person as the Doctor repeated his experiments, so as to remove any remaining doubts by identity of results, or to correct his former experiments, if he considered it necessary to do so.

On common roads a great part of the resistance to the force of traction arises from the friction and shocks occasioned by the inequalities of the surface; and as no material can be found, for road covering, which does not retard the motion of vehicles rolling over it, and that in proportion to the roughness of the material, it is evident that persons extensively employed in the transit of goods, of any description, from one place to another, would soon exert their ingenuity to remedy the cause of resistance, by the substitution of some other material more uniform and smooth, and therefore not liable to the same objections. We accordingly find that various means have been tried, from time to time, to obviate the defects thus complained of. In some places the wheels were made to roll over large blocks of stones, placed closely side by side, presenting an uniform even surface. In other places, beams of timber were used, which sometimes were coated over with sheet-iron, to prevent the wear and tear of those [illegible] most exposed to the action of the wheels. This led to the substitution of iron rails, which have been variously modified, according to the different views and opinions entertained by the advocates of each respective contrivance.

The first description of railways that we read of, consisted of cast-iron rails, termed tram or plate rail; the cross section of which presented a raised edge on the outside, which confined the wheels, and constrained them to run along a bed or plate sufficiently broad to receive the edge of the wheels. This form of rail was found not to answer the purpose proposed: it was difficult to fasten it to the solid supports below the surface of the roadway; the shape rendered it easily broken; and what was worse than all, it formed a receptacle for mud and dust, which of course increased the resistance to the force of traction. This last objection to the tram-rail would soon suggest the idea of substituting edge-rails.

The edge-rail was first constructed of cast-iron; its section was of the form represented in the margin. This form was, in every respect, far better than that of the tram-rail. There was, however, an objection to the material of which it was composed, being very liable to break: the joints were too numerous, the rails being only three feet long. It was found very difficult to connect the rails together, so as to form an uniform surface; which, if made so, would soon become uneven, in consequence of the unequal wear and tear, after the hard exterior of the surface was removed. These defects soon led to

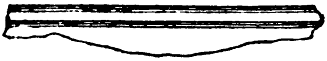
Fig. 1.



the introduction of wrought-iron as a substitute for cast-iron rails.

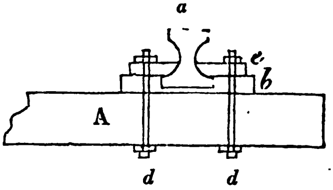
Wrought-iron, on the edge-rail plan, is now in general use. The rails are made of rolled-iron, shaped into any required form, by machinery suitably constructed for the purpose. Repeated experiments have been made, from time to time, with a view to determine the best form of edge-rail. The fish-bellied rail, represented by the accompanying figure, was one pointed out by theory as possessing equal strength throughout. The bars were rolled into lengths of about fifteen or eighteen feet, every three feet of the length presenting in side-elevation a semi-elliptical figure.

FIG. 2.



This form of rail, so far as uniform strength is concerned, answered the end proposed pretty well; but both experiment and theory shew that the straight or parallel edge-rail is the most suitable form, both for strength and equal stiffness throughout; presenting, besides, a cross section of greater stability, with the same area, than any other form of cross section that has been tried. The accompanying figure is a cross section of the parallel edge-rail, which is now very generally used, and which is of uniform depth: the upper table, which is of the same form as that of the fish-bellied rail, is generally two inches at top; the rib is plain, and is generally from six to eight-tenths of an inch in

FIG. 3.



thickness; the lower web is, in some examples, not so wide as the upper table, by nearly half an inch; while in others it is somewhat wider. The total depth, at present, varies between 3½ and 5 inches. The proportions for these parts of the cross section require further experiments to determine the best.

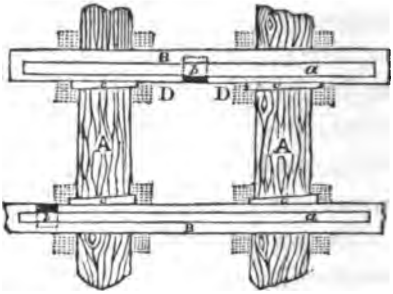
The straight rail has many advantages to recommend it in preference to the fish-bellied rail. It is more easily shaped; answers better for the turnings in a track, as it can be easily cast to any suitable length; and affords greater stiffness and stability.

When the bottom of the fish-bellied rail is a perfect semi-ellipse, (which is hardly ever the case,) great practical difficulties are experienced in rolling the bars, and fitting them upon their supports. The total depth of the fish-bellied rail is usually 5 inches, and the depth at its points of support from 3 to 3¾ inches; the upper table is slightly convex at top, having its angles rounded off, like the straight rail, and is about half an inch thick. The rib is generally one inch thick, and is made in some cases plain, and in others it has a slight protection on one side, near the bottom. In the last figure, *a* is the rail, *b* the chair, A a wooden sleeper to which the chair is fastened, and *c* clamping pieces, which confine the chair by means of the bolt *d*. The first figure is a cross-section of a cast-iron chair and rail, in which *a* represents the rail, *b* the chair, and *c* an iron wedge by which the rail is confined to the chair.

The rails of the Penrhyn railway were first of an oval figure, which were found to wear the wheels, and therefore the oval surface was replaced by a straight one. These rails are of cast iron, and are 4 feet 6 inches long, each weighing 36 ℔, and each sill 14 ℔.

In America, where timber is so very abundant, a combination of this material and iron has been adopted from motives of economy. The same plan has been tried in England, but comparatively on a limited scale.

FIG. 4.



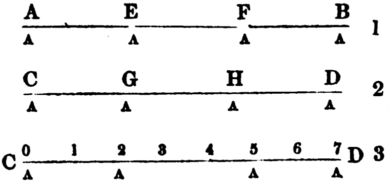
The combination of wood and iron for railways is usually accomplished by fastening a bar of rolled iron on long string pieces of timber, in the manner represented in the accompanying figure, for the wheels to run on. Various ways have been contrived for securing and fastening the materials together. The best plan is to fasten the bars on the top of the beam by means of strong screws, passing through holes of an elliptical shape in the bars, which provides for contraction and expansion. The top of the holes are enlarged, that the head of the screw may not project above the top of the bar. Under the joint, between two bars, a small plate of iron or zinc is let into the string-pieces, to prevent the wood from being crushed by the ends of the iron bars when the weight passes over them. The joint between the bars would answer best in the form of a mitre, as this would have the effect of preventing the sudden shock always experienced in passing over open joints. To obviate this inconvenience, some have adopted a joint like a tenon and mortise.

Stone sills, or string-pieces, have been tried, but were found not to answer the purpose, the bars being constantly getting loose, owing to the disintegration of the stone, from the action of the wheels passing over them.

The foregoing figure represents a plan and cross-section of a combination of wood and iron rail-road. B B are string-pieces, on which the iron plates are fastened; they are usually from six to nine inches in depth, and six inches broad, and may be of any convenient length. A A are cross sleepers, on which the string-pieces are fastened; *a a* are the iron plates on which the wheels run; *b* shews the arrangement of the joints between the plates, *c c* are wooden wedges to confine the string-pieces to the sleepers, and D D are broken stone supports.

The first person who employed malleable iron for the entire rails themselves was Mr. Grieve; but the bars used by him being too slight, were replaced by others of a stronger kind, which answered much better. Mr. Neilson of Glasgow employed edge-rails 9 feet long, $2\frac{1}{4}$ inches deep, and $\frac{3}{4}$ of an inch thick.

There are many reasons which induce us to recommend wrought-iron rails in preference to cast-iron ones: these, with safety, cannot exceed 4 or 5 feet in length, while those may be many times longer, by which more strength is obtained, without any additional loss of material.



If we suppose AB (1) to be made up of three short rails, and its equal CD (2) of one piece, whose extreme points are firmly fixed, the part GH would bear very nearly twice the weight of the middle rail EF. When the rail CD is supported at equal intervals, as represented in the figure, it is not of uniform strength. To render it of uniform strength, divide CD (3) into seven equal parts, and place the supports at the points 0, 2, 5, and 7, making always the parts next the joints, to the middle ones, in the ratio of 2 to 3, which will make them very nearly of uniform strength. This alone is sufficient to recommend the use of long wrought-iron rails.

Mr. Tredgold, in his excellent treatise on rail-roads, gives the following proportions for the different parts of the rails, when made of malleable iron:—An inch in breadth, at the top, for each half ton of stress on one wheel; and the average thickness $\frac{5}{8}$ths of the breadth at top. That profound mathematician says, that if the rails be calculated to sustain the actual stress of one wheel without permanent depression, when of the average or mean thickness, the additional strength gained by the disposal of the parts of the cross-section in the strongest form, will be a sufficient excess in this material, especially when we have the advantage of using it in long lengths, except for inclined planes, which should have stronger rails in proportion to the increased stress upon them.

To calculate the strength for a given stress on a wheel, put $w =$ weight in tons on one wheel, $l =$ length from support to support, in feet; $b =$ breadth of rail, and $d =$ depth, in inches: then according to Tredgold, art. 107, note, we get $2.36\,wl = bd^2$. Now, if we assume $w =$ one ton, $b = \frac{3}{4}$ of an inch, and $l = 3$ feet, then we shall have $2.36 \times 3 = \frac{3}{4} \times d^2$, we shall have $2.353\,l = \frac{3}{4}\,d^2$, and $3.137\,l = d^2$; then $\sqrt{3.137\,l} = d$.

To render this expression easy for practice, we may assume $\sqrt{3.2\,l} = d$, and substituting for l, we get $\sqrt{9.6} = 3\frac{1}{8}$ inches, nearly $= d$. Here the dimensions are 2 inches at top of rail, $\frac{3}{4}$ of an inch mean breadth, 3 feet long, and $3\frac{1}{8}$ inches deep. From this algebraic expression, an easy rule may be given to find the depth capable of sustaining a stress of 1 ton on a wheel. Multiply the distance between the supports, in feet, by 3.2, and extract the square root of the product, for the depth required.

In most railways the upper edge of the cast-iron rails is two inches, where the stress on each wheel is one ton, and the breadth being proportional to the weight (W) on one wheel, it will be as 1 ton : W : : 2 inches : 2 W; which shews, in this case, that the breadth of the top rail ought to be one inch for every half ton of stress on one wheel. The mean thickness of the rails should not be less than half the breadth of the upper side, and the least thickness of the section should not be less than half an inch in any case. No more than one wheel should rest on the unsupported part of the rail at one time, and according to the practice of the best engineers, each rail should be able to bear double the greatest weight that is to be allowed on one wheel.

To find the depth of the rail in inches, let $w=$ weight on one wheel in tons, $l=$length between the supports in feet, $b=$breadth, and $d=$depth in inches; then according to Mr. Tredgold $\frac{2240wl}{850}=bd^2$, for cast-iron, as before, and $5.27\,w\,l=b\,d^2$, when the stress is supposed to be doubled. Now, if we assume $W=1$ ton, $b=1$ inch, the equation will become $5.27l=d^2=\sqrt{5.27\,l}=d$. From this expression we may derive a rule for finding the depth of the rails. Multiply the distance between the supports in feet by 5.27, and extract the square root of the product for the depth required.

Let us suppose the distance between the rails to be 4 feet, then 5.27×4=21.08, the square root of which is 4.6 inches, the depth of the rail.

To find the weight of a cast-iron rail, multiply the area of its cross-section in inches by the length in feet, and this product again by 3.2 for the weight in pounds.

The area of the cross-section is found by multiplying the mean breadth by the depth. And as the weight of each rail is generally given, to a length of 3 feet, or 1 yard, it will answer best to employ 3 as a multiplier.

Let us suppose the mean breadth of the rail to be 1.2 of an inch, depth 4.6, and length 4 feet; then 4.6×1.2=5.52, area of cross-section; hence 5.52×4×3.2=70.656 ℔, the weight required. But using 1 yard as the length, we get 5.52×3×3.2=52.992, or 53 ℔, for the weight.

In laying down the rails on the curved part of the road, if the rail on the outer curve be made higher than the one on the inner curve, it will counteract the influence of centrifugal force, which would have the effect of making the carriage run off the rails in the direction of a tangent to the curve. This may be prevented in another way, which shall be shewn further on. The rails should be curved, as no combination of straight rails could be rendered free from angles, which considerably increase the lateral stress on the rails, causing irregular motion, and much damage in the wear and tear of materials.

To calculate the strength of Tram-rails.—Let

$w =$ stress on one wheel in tons, $l =$ length of bearing, $b =$ main breadth, and $d =$ depth; then $\sqrt{(\frac{3lw}{b})} = d$. This expression will enable us to give a rule in words.

Multiply 3 times the length of bearing, in feet, by the weight on one wheel in tons; divide this product by the breadth in inches, and extract the square root of the quotient for the depth required in inches.

Let 4 inches be the breadth, 4 feet the length, and 1 ton the stress on each wheel; then $\sqrt{\frac{3 \times 4 \times 1}{4}} = d = \sqrt{3} =$ 1.73 inches, the depth required. This depth, combined with the given breadth, will, when fashioned in the best form, be sufficiently strong.

The rails should be of sufficient strength to bear any probable weight that might pass over them, as the time lost in replacing a broken one might often cause great inconvenience and loss of time.

On the Liverpool and Manchester railway, the original rails, which were fish-bellied, weighed 60 ℔ per yard; Loshe's patent rail weighed 44 ℔ per yard; the London and Birmingham fish-bellied rail weighed 50 ℔ per yard; the St. Helen's and Runcorn, 42 ℔ per yard; the rails on the Grand Junction, 62 ℔ per yard; and some of the rails on the London and Birmingham weighed from 64 to 75 ℔ per yard; and the Dublin and Kingstown Railway 45 ℔ per yard.

The experiments of Mr. Barlow and others, leave it questionable whether any additional strength is obtained from a given weight of iron by the fish-bellied shape; and on this account, and more especially on account of the facility of workmanship, the parallel rails are now universally used.

Support of Rails.—The usual support for the rails consists either of large cubical blocks of stone, or of wooden sleepers. These blocks of stone are laid along the tracks, at equal intervals apart, and the chairs which receive the rails, attached to them.

When wooden sleepers are employed, they are laid transversely, at equal distances apart, or longitudinally to support the iron rails. Various contrivances have been tried to fasten the rails to their supports. But this is now universally effected by means of what is termed a chair, which consists of a bed of cast or wrought iron, peculiarly constructed, so as to receive the rail, and be itself easily fastened to its supports.

Fig. 3, represents the transverse wooden sleepers, with the chair and rail. The method of fastening the rail in the chair, and the chair to the support, was long a matter of great difficulty. The chair should be so constructed as to give perfect stability to the rail, by preventing any motion, except what arises from the elasticity of the metal. Care should be taken, too, that the parts have sufficient play for the expansion and contraction of the rail between the ordinary limits of temperature.

The chair represented by Fig. 1, is found to answer the purpose very well. It consists of one piece of cast iron, having a horizontal bed, which rests on the supports, and two upright sides, so shaped as to fit the rail, and allow the insertion of either an iron or wooden wedge, to confine the rail and keep it fast in its place.

Wrought-iron is now superseding the use of cast-iron chairs, this metal being too brittle, and therefore liable to accidents from the sudden shocks it experiences when the train of carriages passes over it. The chair sometimes consists of three pieces, as represented in Fig. 3, the rail being confined by two of the pieces, which are fastened to the third piece or bed, by bolts or nuts. The rail is firmly fastened to the middle chair, allowing it liberty to expand and contract longitudinally from this point towards the ends. This obviates the difficulty of fastening the rails, so as to prevent the great strain experienced from expansion and contraction when the rail is firmly fixed to each point of support.

The chairs are fastened to the stone supports, by first drilling two holes in the block to receive strong oak pins, and then driving an iron bolt into each of these pins, through holes which are left for them in the bed of the chairs.

Other supports are found to answer much better than stone blocks, which, besides other objections, are very apt to split, and let loose the chair. The pins connecting it to the block invariably wear large holes in the latter, by which all the parts are disengaged and then set free.

A firmer fastening is made with wooden sills, by inserting iron screw-bolts in holes bored entirely through the sill, putting the head of the bolt beneath the sill, and confining the chair to the sill by means of nuts screwed tight on the projecting ends of the bolts.

In cases where the rail consists of a combination of wood and iron, the string-pieces are laid on stone blocks, similar to the way in which rails formed entirely of solid iron are fixed. In a combination of this sort, the chair consists of two upright pieces of cast-iron, which are fastened to the block, the string-pieces being confined to the chair by means of screw-bolts, secured by nuts:

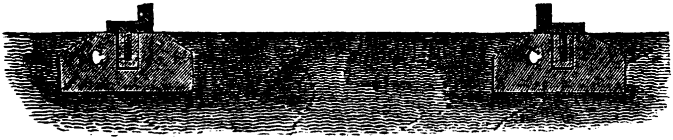
sometimes the string-pieces are laid on cross sleepers, with notches cut in them to receive the string-pieces. In this case, the string-pieces are fastened by means of wooden wedges. Great care should be taken to secure the blocks or cross-sills, which ever is used, to the soil, which is effected by sinking them into holes or trenches of sufficient capacity, and then ramming the fresh earth round them. A better way, however, would be, to rest them upon a layer of broken stones, and secure them with earth or coal-ashes firmly rammed. This kind of support drains off the water, which in the last case is found to do much mischief, especially in frosty weather. Nothing should be attended to with stricter care than the drainage of the subsoil under the railway track. It is not unfrequent to remove the entire of the natural soil, and replace it by another more favourable to the free passage of water.

In swamps and bogs, the works should be laid on an embankment erected on brush-wood, which forms the best foundation in such places. Stone blocks were first used as supports on the Dublin and Kingstown railway; but now the rails are laid on longitudinal pieces of timber, which are connected and kept parallel by smaller pieces placed transversely at proper distances. This is found to be a vast improvement, as the trains pass over the rails smoothly, without experiencing those constant shocks invariably felt in passing over rails fastened to granite sleepers. On the Greenwich railway the stone supports are replaced by longitudinal sleepers of wood, as on the Dublin and Kingstown line.

In selecting the best route for a turn-pike road, railway, or canal, special regard has been paid to the level.

This, though a primary object in the selection of a road or canal, is not the only one that requires much skill, profound judgment, and discriminating views on the part of the engineer. When a railway is proposed to be constructed between any two points, the engineer must ascertain whether or not the traffic is mutual and equal between them. If the same quantity of goods or number of passengers pass from one point to the other respectively, then the best line is that on which the journey may be performed in the shortest time, with the least expenditure of power, and at the smallest expense. In this case the engineer should seek the best level.

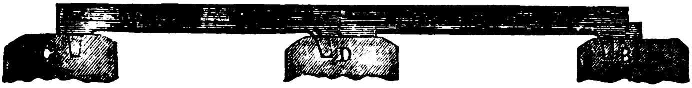
Tram-roads, or flat Rail-roads.—The tram-road is very convenient for temporary uses. The accompanying figure is a section of a tram rail-road, which exhibits weakness of construction, though very useful in mines and quarries, in the formation of canals, roads, and in conveying materials for building. When the strength of these tram-rails is not equal to the work required, a rib is added to the under side, which renders them much stronger than the common tram-rail. This description of rail is fastened with spikes, upon cross-sleepers of wood, and when intended for permanent use, they are fastened with iron bolts driven into wooden plugs, previously inserted into large blocks of granite which support the rails. Mr. Wilson obviated the

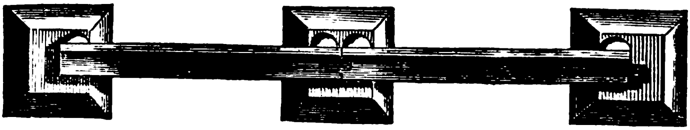


difficulty of keeping the joints even and in their proper places, by resting the ends on a saddle-piece. When the tram-rails are not sufficiently strong to bear a great weight, it is the usual practice to distribute it over a large space, by dividing it into several parts, and employing a number of small carriages instead of one.

By this practice, which is no doubt a very desirable one, so far as the safety of the rails is concerned, the effect of the power is considerably diminished, in consequence of the small carriages requiring small wheels. Mr. Le Caan has invented a method, by which much time is saved in putting down and taking up tram-rails, without using nails.

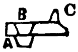
The accompanying figure is a longitudinal section of two plates fixed on their sleepers, C, D, B. From the figure here exhibited, it may be seen that the plates are joined by a dove-tailed notch and tenon, an oblique plug having been cast on each plate, which fits into a mortice prepared for its reception in the sleepers. At about every thirty yards distance is a perpendicular plug, which facilitates the removal of any particular plate that may have received injury. The plate to which this perpendicular plug is attached is called a stop plate.





The plan of two of the plates, with the blocks that support them is here annexed. The holes to receive the plugs should be three inches deep, and counter-sunk, so that the end of the plate may rest firmly on the block that supports it.

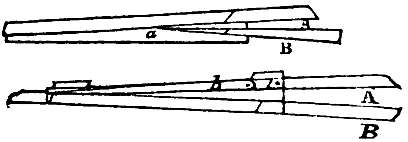
The accompanying figure is the end of one of the plates, where C shews the flange, B the sole on which the wheels run, A one of the plugs, and a projection behind, by which the plate is made to lie more firmly on the stone block.



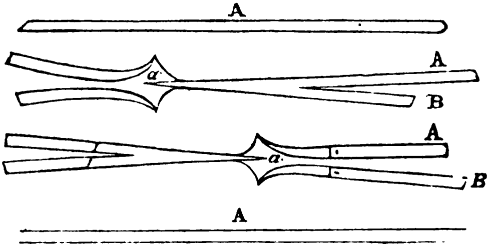
The dimensions of all these parts require particular attention. When any part is too weak, its repairs must necessarily create expense; and when more material is employed than the work upon the line requires, the redundant quantity becomes an unnecessary expense. This is an observation that applies to all the machinery connected with every railway project, which proves the necessity of applying the results of experimental science to the due proportioning of the whole. The diameter of the plug near the shoulder is 1¾ inches, and at the point only 1 inch; its length is 2½ inches, and its obliquity somewhat about 8 degrees. The plates are usually 3 feet long, the flange 1½ inch high, the sole or bed about 4 inches broad and ¾ of an inch thick, and the weight of each plate is generally 42 ℔. A small groove runs along the exterior of each plug, whose office is to allow the water to expand in the hole in frosty weather. The ends of the plates are usually ¼ of an inch thicker than any other part. The sleepers or blocks on which the rails rest should not weigh less than 1½ cwt.

All these dimensions should vary according as the circumstances of the case may require.

Arrangements for passing from one track to another.—When a rail consists of a single track, a contrivance, termed a siding, is made to pass from the track at one point, and enter it at another, by which trains are allowed to pass each other. If the part of the main track, where the siding is required, be straight, it may be on either side; but if it be curved, the siding must be placed on the concave side. There is no positive limit laid down for the angle of deflection of the siding, being dependant on the distance between the siding and the main track, and the longest train of carriages that is likely to pass over the track at one time. The angle of deflection should be as small as possible, that the change from one track to another may be as gradual as possible. The accompanying figure represents a siding, where A is the main track, and B the siding. When the line has a double track, an arrangement similar to a siding, which is termed a crossing, is made, to enable the train to pass from one track to another. Both the sidings and crossings are placed on particular points of the line where its peculiar service may require them.



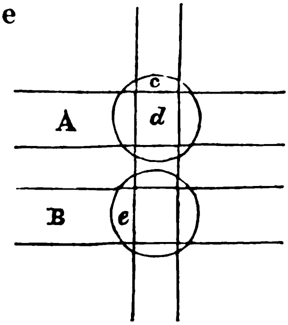
The accompanying figure represents a crossing, in which A is the main track, and B the track of crossing.



All this arrangement is so contrived that the train may continue on the main track, or depart from it at pleasure, either into the siding or crossing. To effect this, a portion of the track, or of the siding at the point of separation, is made moveable, so that in one position it will form part of the track, and when displaced, will allow the train to get into the siding. This moveable part is termed a switch. By referring to the second last figure, *a* is a fixed switch, and *b* a moveable switch. In the last figure, *a a* are termed turn-outs, which are placed at the points where the rails of the crossing or siding, cross those of the main track, and so disposed that no impediment is offered to the wheel in its course, either along the main track, or along the crossing. These moveable bars are turned from one direction to another by means of very simple machinery, which are placed near the track, out of the reach of the carriages. A long rod of iron connects the end of a lever and the switch, by which motion is given to it to the right or left, according as the circumstances of the case may require. When there is but one track, the passing places must be much more frequent.

Turn-tables.—These are used in transferring single carriages from one track to another. This is accomplished in a much shorter time, and with greater facility, than by any arrangement of crossings and switches. These turn-tables consist of circular platforms of iron and wood, fixed on the same level with the tracks, and mounted on friction wheels, so as to be easily turned on their centres.

The annexed figure represents two turn-tables, so arranged as to communicate with each other. The figure exhibits four rails laid across each other, and made to tally with those of the track. Now, when it is required to transfer a carriage from the track A to the track B, it is first rolled on the turn-table at *d*, and then releasing the catches which hold the table steady, the platform, with the carriages upon it, is turned a quarter round; and keeping *d* in this position, the carriage is rolled on the turn-table *e*, which is turned a quarter round, by which the carriage is brought to a position in which it may be rolled on the track B.



If, in place of transferring the carriage from one track to another, parallel to it, it be only required to transfer it to one branching from it at any angle, it is done by rolling the carriage on the platform *d*, and turning it round a portion of a circle, which brings the carriage into a position in which it may be rolled along the cross track B. Locomotive engine-houses are often made octagonal, with eight radiating tracks, on any of which the engines are moved by means of a large turn-table in the centre.

Captain Handcock has taken out a patent for an improved turn-table, which is most likely to supersede the use of those usually employed. From its palpable superiority, it has been introduced on the London and Birminghan, Great Western, and other lines. It works on a pivot instead of the old plan of rollers, by which nearly the whole of the friction is done away with. The table is supported by stays, connecting the outer rim with the base of the moveable pillar on which the pivot works, any inequality in the pressure being relieved by the use of anti-friction rings.

Road-way.—From the instructions already given for making turnpike roads, little remains to be said on making the road-way, and keeping it dry. It cannot be too strongly impressed on every engineer employed in railway practice, to adopt every precaution for keeping the road perfectly dry. He should avoid the use of materials which are known to absorb and retain water, than which nothing is more injurious; he should also provide for the drainage of every part of the line, and especially in deep cuttings, not much exposed to the drying influence of the sun and atmosphere. When the trenches under the rails are filled with broken stone, similar to what we use for common roads, and cross stone drains made at proper distances, with a sufficient descent towards the side drains, the drainage of the road-way will be effected. When embankments are composed of absorbent materials, proper drains should be made at its base to carry off the water.

All slopes should be provided with oblique drains, to prevent the destructive effects of water, which, if not properly directed, would soon wear out deep furrows down the slopes, produce land-slips, and choke the lateral and side drains at the bottom.

Grass-seeds ought to be sown in slopes, which, when grown, will protect them from the influence of rain. It is a good plan to cover the sides with sods, which very soon take root, and serve as a protection. When the sods are laid on in dry weather, they should be watered morning and evening, till they are found to take root. A neglect of this duty often renders the sodding quite useless, as without a sufficient quantity of moisture to promote vegetation, the entire covering soon becomes parched, separating altogether from the surface of the slope, which it was intended to protect. Too much care cannot be bestowed on slopes and embankments, to prevent land-slips, the disastrous consequences of which, on one of the English railways, must be fresh in the recollection of most readers.

The angles at which slopes, composed of different materials, are found to stand, shall be given in another place, where the subject will be resumed.

The best method of making embankments shall be described under its proper head. When embankments are not properly made, slips are sure to take place, by which travelling is rendered dangerous.

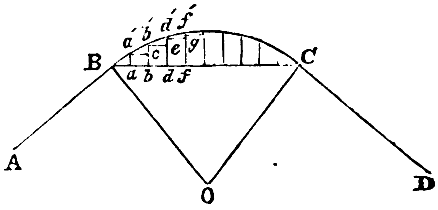
When the traffic is unequal, or when heavy goods are to be transmitted from one place to another, while light goods only return the contrary direction ; then the most level line may not best answer the purpose. In this case there is no doubt but that the heavy loads ought to descend along the line, and that with an inclination best adapted for the particular traffic. The best inclination for a descending traffic is that which imposes equal labour on the motive power in ascending and descending. To find the inclination, let $W =$ descending weight, including the weight of carriages, &c., and let $nW =$ ascending traffic, including the weight of carriages, &c. Now, only the same quantity of power is to be expended in ascending and descending ; therefore, according to Mr. Tredgold, we shall have $W(\frac{fr}{R} - \sin\ i) = nW\ (\frac{fr}{R} + \sin i)$; or dividing by W,

$\frac{fr}{R} - \sin i = \frac{nfr}{R} + n \sin i$, and by dividing by n, we get $\frac{fr}{nR} - \frac{\sin i}{n} = \frac{fr}{R} + \sin i$, and by transposition we get $\frac{fr}{nR} - \frac{fr}{R} = \frac{\sin i}{n} + \sin i$, or $\frac{fr - frn}{nR} = \frac{\sin i + n \sin i}{n}$, or $\frac{(1-n)}{R} fr = (n+1) \sin i$; and $\sin i = \frac{1-n}{1+n} \times \frac{fr}{R}$. Now, if both trades be equal $n = 1$, which being substituted in the above equation, we get $\sin i = 0$, which shews that there should be no inclination in the road, but should be perfectly level. When the loads going down the inclined plane are double, treble, &c. the loads coming up, including the weight of the carriages, the above formula bears upon the case.

In the above equation, r is the radius of the axles, R the radius of the wheels, and f the friction when the pressure is 1. Let us suppose the weight drawn up is only half that drawn down the slope, then $n = \frac{1}{2} = .5$; and let $f = \frac{1}{8}$, $r = 3$ inches, $R = 36$ inches; then we get $\frac{1}{8} \times \frac{3}{36} \times \frac{.5}{1.5} = \sin i$; that is, $\frac{1}{8} \times \frac{1}{12} \times \frac{1}{3} = \frac{1}{288} = .0034$.

In this example, we have assumed $\frac{1}{8}$ of the pressure to be equal to the friction, which, in case of bad and clumsy workmanship, is perhaps too little; but when the work is well finished, and kept in good order, $\frac{1}{8}$ of the pressure is perhaps too much for the friction.

In laying out a rail-road, the direct course is often interrupted by a steep hill, a town, or private building, which it would be advisable to avoid, by changing the direction so as to get clear of the object; and having got clear of the impediment, the former direct course may be resumed, or some other struck out. But as the straight portions of the line are always to be connected at the points of change of direction, by an arc of a circle, to which these straight portions are to be tangents, it may be necessary to show how the operation should be conducted in the field, upon true scientific principles. We have seen a modern author fall into a mistake in this particular part of railway surveying, owing evidently to a want of knowledge of the elementary principles of geometry.



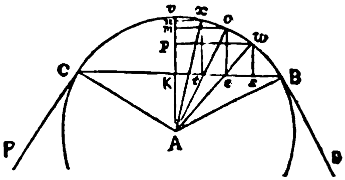
Let AB and CD be two portions of a straight road, whose extremities B and C are to be connected by an arc of a circle, to which both are to be tangents. Having surveyed from A to B, fix the theodolite at B, and if the point C be visible, take the angle ABC; but if the point C should not be visible, find its direction from B, and place a staff any where in the direction, as at *a* or *b*, which will enable you to measure the angle ABC. Having found the measure of this angle, the next thing to be done is to measure the distance BC, either by the chain or some other method shewn in the preceding part of this work; then plot the work, that is, draw AB of any convenient length, make the angle ABC equal to the measured angle, lay off the distance BC from a scale of equal parts (adopting a large scale), at the point C make the angle BCD equal to the angle ABC, erect the two perpendiculars BO, CO, and from the centre O, with the radius BO or OC, describe the arc B a' b' f' d' C, which will represent the curve required. Divide the line BC into any number of equal parts, so as that each division may not exceed two chains of fifty feet each; at each division erect the perpendicular ordinates *aa′*, *bb′*, &c., and find their lengths respectively off the same scale to which you plotted the figure. Then proceed to the point B, on the field, and measure the distance B*a*, in the direction of B C; at *a* measure the ordinate *aa′*, and placing a picket at *a′*, measure *a′c* at right angles to *a a′*, and equal to *ab*; having arrived at *c*, measure the line *c b′* at right angles to *a′c*, and equal to the difference between *a a′* and *b b′*. Having fixed a picke at *b′*, measure the line *b′e* at right angles to *b b′*, and equal to *d b*, and measure the line *e d′* at right angles to *c d′*, and equal to the difference between *b b′* and *d d′*, and at *d′* fix a mark: in this way you proceed to the crown of the arc. The other half of the arc is determined in a similar manner, except that the difference between every two adjacent ordinates is laid off towards the line B C.

Now having the points B, *a′*, *b′*, *d′*, &c. marked on the ground, they may be joined by a regular curve; but if these points be too far asunder, so as to make it difficult to connect them by a regular curve, then intermediate ordinates might be measured, giving intermediate points in the curve.

This method is the easiest and most practical that could be employed in laying out curves in the field. It is sufficiently accurate, when due care is taken to plot the respective dimensions accurately to a large scale.

The length of all the ordinates are found by the following trigonometrical calculation:

The angles ABC and BCD are each 121°, and BC 4000 feet. The ordinates are found in the following manner: Through *t*, *e*, *s*, draw the ordinates at right angles to CB; draw *nx*, *mo*, &c. parallel to CB: these parallels are given, being equal to *kt*, *ke*, &c. Join A*x*. Also the angle ACB is given, being equal to 121°—90=31°. Then to find the radius A*x* or AC; we have given C*k*= 2000, the angle CAK=59°.



As sin. ∠CAK 59°	...	9.9330656
is to CK 2000	...	3.3010300
so is rad. 90°	... ...	10.0000000
		13.3010300
		9.9330656
to AC=A*x* 2333	... ...	3.3679644

To find AK:

As cos. 31°	... ...	9.9330656
is to CK 2000	... ...	3.3010300
so is sin. 31°	... ...	9.7118393
		13.0128693
		9.9330656
to AK 1202	... ...	3.0798037

Then A*x*—AK = 2333—1202 = 1131 = K*v*, the middle ordinate.

To find the angle *n*A*x*:

As A*x* 2333	... ...	3.3679644
is to R 90°	... ...	10.0000000
so is *nx* 500	... ...	2.6989700
		12.6989700
		3.3679644
to sin. ∠*n*A*x* 12° 23′	...	9.3310056

To find *tx* :

As R 90°	10.0000000
is to A*x* 2333	3.3679644
so is cos. $\angle$ *x*A*x* 12° 23 ...	[illegible]
	[illegible]
	10.0000000
to A*n* 2279	[illegible]

Then 2279—1202=1077=*tx*

To find the angle *m*A*o* :

A*o* 2333	3.3679644
is to R 90°	10.0000000
so is *mo* 1000	3.0000000
	13.0000000
	3.3679644
to sin. $\angle$ *m*A*o* 25° 22′ ...	9.6320356

To find *oe*

As R 90°	10.0000000
is to A*o* 2333	3.3679644
so is cos. $\angle$ *m*A*o* 25° 22′ ...	9.9559689
	13.3239333
	10.0000000
to A*m* 2108	3.3239333

Then 2108—1202=906=*eo*.

To find the angle *p*A*w* :

As A*w* 2333	3.3679644
is to R 90°	10.0000000
so is *pw* 1500	3.1760913
	13.1760913
	3.3679644
to sin. $\angle$ *p*A*w* 40° ..	9.8081269

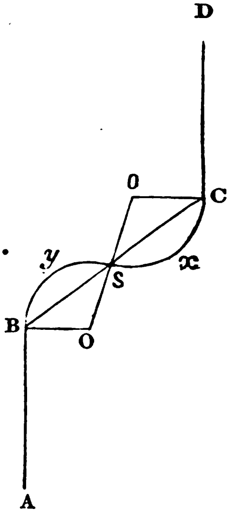
To find *sw*:

As R 90°	...	...	10.0000000
is to A*w* 2333	...	...	3.3679644
so is cos. 40°	...	...	9.8842540
			13.2522184
			10.0000000
to A*p* 1787	...	...	3.2522184

Then 1787−1202=585=*sw*.

The ordinates *kv*, *tx*, *eo*, *sw*, being found, the corresponding ordinates on the other side of the ordinate *kv* are determined. Having the ordinates and their distances apart, the points *v*, *x*, *o*, *w*, &c. are found on the ground, as shewn before.

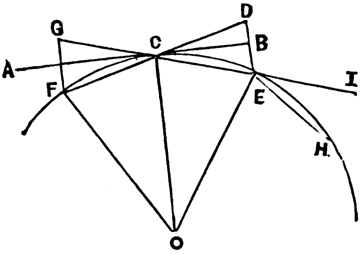
It is often required to connect two parallel directions, AB and CD, by a curve of contrary flexure, resembling the letter S. To effect this on the ground, you plant the theodolite at B, and measure the angle ABC, which is equal to the angle DCB; measure also the distance BC. Having obtained these two dimensions, plot the lines AB, BC, and CD, making the angles ABC and BCD equal to the measured angle; bisect BC in *s*, erect the perpendicular BO to AB, and at *s* make the angle B*s*O equal to the angle *s*BO; then from O as a centre, with the radius BO describe the curve B*y*S. Again, to the line CD erect the perpendicular C*o*, and make the angle *os*C equal to the angle *o*C*s*: then from the centre *o*, with



the radius oC describe the curve sxC. Having the figure thus constructed, measure any number of equidistant ordinates off the same scale to which the line BC was laid down, and measure these ordinates on the ground, as was taught in the last case; or calculate the ordinates to both curves, by the method shewn in the case of a single curve, and lay them off on the ground by the method shewn in the same article.

Curves on rail-roads should never, if possible, be so abrupt as to require the train to pass over them with any considerable diminution of speed. And as a further precaution for safety, both the curved part and the approaches to it should be comparatively high. A curve of ¾ of a mile radius, with a rise of 16 feet in a mile, reduces the speed of a locomotive nearly one-half. A curve of a quarter of a mile radius on the Bolton and Leigh Railway, is passed with safety at the rate of 30 miles an hour.

The following method of passing from a straight line into a curve of a given radius, was communicated by Mr. Bourns, C.E., to the Institution of Civil Engineers, of London.



Let AB be a straight line, it is required to lay out the curve CEH, so as to pass into it from the straight line. O is the centre of the curve, C the point at which the line AC is to touch it, FC and CE are each one chain; produce FC so as to make CD equal to FC, and join DE. By producing AC, it is evident that DB = BE. In the similar triangles OCE and CDE, we have $OC : CE :: CE : DE$. Hence $DE = \frac{CE^2}{OC}$; that is, the offset is equal to the chord squared, divided by the given radius of the curve. If we suppose the radius of the curve to be 100 chains, and the chord 1 chain, then all being reduced to inches, we have,

$100 \times 792 : 792 :: 792 : 7.92$ inches $= \frac{792 \times 792}{100 \times 792} = \frac{792}{100} = 7.92$. Now $BE = 7.92 \div 2 = 3.96$ inches, and $CE = 792$, we get $CB = \{(792)^2 - (3.96)^2\}^{\frac{1}{2}} = 791.99$ inches. Hence the construction on the ground.

Take $CB = 791.99$ inches, which is one chain, wanting the one hundredth part of an inch, and lay off the perpendicular $BE = 3.96$ inches, by means of a staff divided for the purpose; then will E be a point in the curve. Next, produce CE to I, making EI equal to one chain, and holding the end of the chain fast at E, move the other end towards H, till the distance IH become $= 7.92$ inches, the calculated offset. In a similar manner, one chain is measured on EH produced, and the calculated offset laid off, as before.

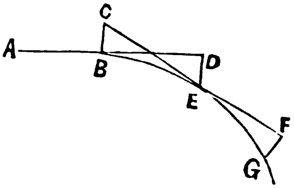
When it is required to pass from the curve HEC to the straight line CA; produce EC to G, making CG = one chain, and lay off GA in the proper direction, equal to half the ordinate GF; then CA may be produced at pleasure. The chain here used is the four pole chain of 792 inches. In somewhat a similar manner may a curve of a given radius be passed into another of lesser or greater radius.

By the above formula, the following table of offsets for setting out railway curves, has been constructed:

Radii in Chains.	Offsets.	Radii in Chains.	Offsets.	Radii in Chains.	Offsets.
	Ft. In.		Ft. In.		Ft. In.
10	6 7.2	41	1 7.3	72	0 11.0
11	6 0.0	42	1 6.9	73	0 10.8
12	5 6.0	43	1 6.4	74	0 10.7
13	5 0.9	44	1 6.0	75	0 10.6
14	4 8.6	45	1 5.6	76	0 10.4
15	4 4.8	46	1 5.2	77	0 10.2
16	4 1.5	47	1 4.8	78	0 10.1
17	3 10.6	48	1 4.5	79	0 10.0
18	3 8.0	49	1 4.1	80	0 9.9
19	3 5.7	50	1 3.8	81	0 9.7
20	3 3.6	51	1 3.5	82	0 9.6
21	3 1.7	52	1 3.2	83	0 9.5
22	3 0.0	53	1 2.9	84	0 9.4
23	2 10.4	54	1 2.7	85	0 9.3
24	2 9.0	55	1 2.4	86	0 9.2
25	2 7.7	56	1 2.1	87	0 9.1
26	2 6.5	57	1 1.9	88	0 9.0
27	2 5.3	58	1 1.7	89	0 8.9
28	2 4.3	59	1 1.4	90	0 8.8
29	2 3.3	60	1 1.2	91	0 8.7
30	2 2.4	61	1 1.0	92	0 8.6
31	2 1.6	62	1 0.7	93	0 8.5
32	2 0.8	63	1 0.5	94	0 8.4
33	2 0.0	64	1 0.3	95	0 8.3
34	1 11.3	65	1 0.2	96	0 8.2
35	1 10.6	66	1 0.0	97	0 8.1
36	1 10.0	67	0 11.8	98	0 8.0
37	1 9.4	68	0 11.6	99	0 8.0
38	1 8.8	69	0 11.3	100	0 7.9
39	1 8.3	70	0 11.3		
40	1 7.8	71	0 11.1		

From the foregoing table, it appears that the offset of a given curve is equal to half the offset of a curve of half the radius, and equal to double the offset of a curve of double the radius. Thus the offset of a curve of 40 chains is equal to half the offset for one of 20 chains, and double the offset for one of 80 chains. Therefore, the foregoing table will answer, with very little trouble, for curves with radii as high as 200 or 400, &c. chains.

To lay out a curve in a Tunnel.—Let AB be a straight line, it is required to pass from it into the curve BEG, the radius being 100 chains.



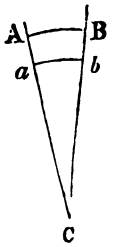
Lay out BD equal to one chain, and at D lay off DE at right angles to it, and equal to 3.96 inches; then E will give a point in the curve. Next, erect BC at right angles to BD, and equal to DE; then connect CE and produce it to F, making EF equal to one chain; at F set off the offset FG, equal to 3.96 inches, as before, and in this manner you proceed to the end of the curve. This, in practice, is a work of considerable difficulty.

It is even a work of difficulty to keep the centre of a straight tunnel in the proper direction, when the work is carried on from both extremities, and from shafts sunk at intermediate points, at the same time. When the shafts are not very deep, the usual mode of proceeding is to fix two plumb-lines in the centre line at the surface, in the mouth of each shaft, having them of sufficient length to range from below. From the great depth of the shafts sunk in the Box-tunnel on the Great Western Railway, (some of them from 300 to 400 feet in depth,) the plumb-lines oscillated so much from the effects of air currents, that their use was discontinued; the following method having been practiced. Having sunk shafts of 20 feet in diameter, and fixed the centre line at these shafts, on the surface, by the theodolite or transit instrument; then placing the instrument alternately at the two opposite points in the centre line, at the mouth of the shaft, let two points be marked below by means of the vertical arc, and these points being joined and produced both ways, will give the proper direction.

Method of determining the elevation of the exterior rail of a curved track, allowing the rim of the wheels not to be conical.

A carriage, in going with considerable velocity on a curved track, exerts a certain influence in the direction of a tangent to the exterior rail, by which it is continually in danger of being thrown off the track. To counteract the influence of centrifugal force, it will be necessary to raise the exterior rail above the level of the interior one, by which the centre of gravity of the carriage is made to tend inwards. A familiar illustration of this contrivance may be seen in the case of a horse going round a circus, the horse and driver leaning inwards in proportion as the velocity increases. Hence the manifest necessity of making a small ascent to the middle of the curve of the exterior rail, by which not only the safety of the train is secured, but the rubbing of the flanges of the wheels against the rail prevented.

On a curved railway, the wheel on the exterior curve passes over a greater distance in the same time than that on the interior, by which the former is partly dragged. On a mixed line of railway, this last can hardly be obviated; but when the carriage constantly goes round a circle, the diameter of the exterior wheel may be made to exceed that of the interior by such an amountas to make both wheels revolve in their respective tracks without dragging. These three sources of danger, retardation, and damage, are obviated in a circular railway, once intended to be constructed by the author on his own premises.



To make both wheels go round their respective tracks, without either of them being in danger of dragging; let us assume the space Aa between the tracks equal to s, d the diameter of the wheel on the interior track, D the diameter of the wheel on the exterior track, and C the centre of the curves ab, AB. Now, as the wheels must revolve an equal number of times on their respective rails, it is evident that the circumferences of the wheels must be to each other as the circumferences of the rails upon which they run; but the circumferences of the wheels and rails are as their diameters; therefore, putting $a\text{C}=r$, and $\text{AC}=\text{R}$, $d:\text{D}::r:\text{R}=(r+s.)$ Hence $\text{D}=\frac{d\times(r+s)}{r}$. In the circular railway above alluded to, the diameter $a\text{C}=(r)$ is 10 feet, the space s, between the rails, 1 foot, and the diameter d, 8 inches: hence $\text{D}=\frac{8\times(10+1)}{10}=\frac{8\times 11}{10}=\frac{88}{10}=8.8$ inches.

To provide against the danger of going in the direction of a tangent, from the influence of centrifugal force: let f represent the centrifugal force, M the mass of the vehicle, v the velocity with which it moves on the curved track, and R the radius of the circle described by the centre of gravity of the vehicle; then by a well known formula in dynamics, we get $f=\text{M}\frac{v^2}{\text{R}}$ (see page 147 Simpson's Fluxions, or page 108 Leslie's Philosophy,) but by Corollary, page 14, Woods' Mechanics, the momentum, moving force, or weight, varies as the accelerating force and quantity of matter conjointly, that is, $\text{M}g=\text{W}$, and therefore $\text{M}=\frac{\text{W}}{g}$, M being the mass, g the accelerating force, and W the weight; and substituting $\frac{\text{W}}{g}$ for M, in the expression which gives f, we get $f=\frac{W}{g}\frac{v2}{R'}$ for the value of the centrifugal force of the vehicle. To apply this to the case in point, it is manifest that as the force f acts outwards, the force to counteract it must act inwards. This counteracting force is that of gravity, which tends to move the vehicle inwards, contrary to the direction of the centrifugal force, when the exterior rail is raised somewhat higher than the interior one. To find how much the exterior rail should be raised, so that the component of gravity along the inclined plane inwards, may be equal to the amount of the centrifugal force acting outwards; put the elevation $= x$, and the difference between the diameters of the wheels, which is .8 of an inch $= d'$, the altitude of the inclined plane will be $y+d$. But by cor. 2, page 134, Wood's Mechanics, the component of gravity along an inclined plane is expressed by the weight of the body multiplied by the ratio of the altitude, to the length of the plane; but the length of one plane in this particular case is 12 inches $(= L)$; therefore, this component will be $W\times\frac{d'+s}{L}$. Hence the condition of equilibrium will be be fulfilled, when $W\times\frac{d'+x}{L'}=\frac{W}{g}\times\frac{v2}{R'}$: whence $x=\frac{Lv2-dgR'}{gR'}$.

In the present case, $v=3$ miles per hour, or 4.4 feet per second, $R'=5$ feet, $d'=.8$ of an inch, $L=1$ foot: then $v^2=19.36$, and $dgR'=5\times32\frac{1}{6}\times.8=128\frac{2}{3}$, and $128\frac{2}{3}\div12=10.8$ feet nearly: then $\frac{19.36-10.8}{32\times5}=\frac{8.56}{160}=\frac{8.56\times12}{160}=.6$ of an inch for the value of x nearly, g being $32\frac{1}{6}$ feet.

When the velocity exceeds that given above, the centrifugal force will be increased, and the flanges will rub against the inside of the rails; on the contrary, when the velocity is less, the centrifugal force will be diminished, and the flanges will rub against the outside of the rails.

Hence it appears, that upon curves, the velocity must neither exceed, nor fall short of, that for which the rails had been constructed.

When the railway consists of straight lines and curves, the rims or edges of the wheels must be made slightly conical, the diameters within the track being greater than those without it.

This contrivance is adopted by the best engineers, while others prefer to raise the central part of the rail of the exterior curve a little, by which the danger of going off the track is prevented.

A curve on a railway is not of much consequence, provided the ground is even; the wear and tear, however, is very considerable; therefore, both abrupt curves and slopes should, if possible, be avoided.

Equalizing the excavations and embankments.—After having determined the direction of the line, from a careful comparison of the several trial lines, the next point of importance to be attended to, is the balancing of the excavations and embankments; that is, to regulate the slopes in such a way, that the materials cut from the heights may be just sufficient to fill up the hollows, so as to bring the surface of the road-way to the required inclination. To effect this, a great variety of slopes must be assumed, and the calculations of all the cuttings and embankments compared. The result of this comparison will point out that slope which combines most advantages.

In making these trials, it is not expected that the road throughout is to have only one unvaried inclination.

Few surfaces could be found to admit of this, for any considerable distance; therefore, the proper way would be to divide the entire line into several parts, and equalize these, taking due care that the rise or fall, at the connecting points of these subdivisions, be not too abrupt, avoiding in every case, if possible, such ascents and descents as would require the use of a stationary engine. The solution of this problem cannot be arrived at without the aid of calculations, founded on considerations involving time, labour, and expense. If the expense of cutting and embanking should be found to exceed the present sum that would compensate "for the delay and expense of the engine, its apparatus, attendance," &c. then of course a stationary engine ought to be employed. A good knowledge of geometry is of the utmost importance in equalizing the excavations and embankments on a railway. Without a thorough knowledge of this branch of science, the engineer's time and labour will be expended in vain, in approximating an object which can never be attained by any one unacquainted with science. In taking the levels on the line, it will be required to take not only the longitudinal levels, but the cross levels also. The cross-levels form a necessary element in the data required in the solution of this problem, as by means of the two, the excavations and embankments may be calculated, from the likeness of their subdivisions to some geometrical solid, such as aprism, prismoid, wedge, or pyramid.

In equalizing the volumes of the excavations and embankments, it may be necessary to mention that some earth, in its natural state, occupies less space than when dug and broken up; while other descriptions of earth occupies more. For instance, in the London clay, it will be found that any quantity of cutting will not make the same quantity of embankment by about 10 per cent., whereas in common earth, just the reverse takes place, and the cutting will make an embankment nearly 10 per cent. greater. In making embankments, this must be allowed for.

Mr. M'Neil has published a work, containing tables which facilitates the calculations relating to cuttings and embankments. He gives the amount of cutting in cubic yards, at various slopes, and for all depths not exceeding 50 feet. When you have balanced the cuttings and embankments, you mark the axis of the road, by placing pickets at equal distances asunder, and numbering them to correspond with the same points on the map. You also put stakes along the lines of the cross-profiles, to mark the side-slopes of the excavations and embankments, and the width of the road-way. It would be well to mark the stakes, to indicate their position on the map, and also to shew the depth of excavation and height of embankment, which will serve as a guide to the workmen during their operations. The map should shew all these points and numbers, corresponding to the pickets, excavations, and embankments. The general map should be accompanied by other detailed maps of the different divisions of the line, drawn to a large scale, showing the longitudinal and cross sections of the natural ground, the vertical heights of the different points above the datum line, the excavations and embankments, and the road-way, with the horizontal dimensions of all these parts.

The superintending engineer should be furnished with detailed drawings of all the other works to be done on the line, such as bridges, culverts, viaducts, &c., with written specifications, showing the manner in which every part of the work was to be executed.

By the standing orders of Parliament, it is required "that a plan, and also a duplicate of such plan, on a scale of not less than four inches to a mile, be deposited for public inspection," &c. "which plan shall describe the line or situation of the whole work, and the lands in or through which it is to be made, maintained, varied, extended, or enlarged, or through which every communication to or from the work shall be made," &c. *(See the Plan.)*

It may be well to embrace within the limits of the road survey a space not exceeding five chains on each side; as an occasion may arise wherein it might be necessary to apply for power to deviate to the extent of one hundred yards on either side the original line. The standing orders also require "that in all cases where it is proposed to make, vary, extend, or enlarge any railway, the plan shall exhibit thereon the height of the several embankments, and the depth of the several cuttings respectively." &c. *(See the Plate.)* "That the section for a turnpike road, cut, canal, reservoir, aqueduct, or railway, shall be drawn on the same horizontal scale as the plan, and to a vertical scale of not less than 1 inch to every 100 feet; and shall show the surface of the ground marked on the plan, and the intended level of the proposed work, and a datum horizontal line," &c. "That in every section of a railway, the line marked thereon shall correspond with the upper surface of the rails," &c. *(See PP on Plate.)*

"That a vertical measure, from the datum line to the line of railway, shall be marked in feet and inches, at every change of inclination, and that the rate of inclination between each such change shall also be marked," &c. *(See the Plate GH.)* "That the height of the railway over or under the surface of every turnpike road, navigable river, canal, or railway, or junction with a railway, shall be marked in figures at each crossing thereof; and if there shall be no such crossing in every half mile, then the height over or under the surface of the ground shall be marked once in that space; and if any alteration in the present level or rate of inclination of any turn-pike road, carriage road, or railway, be intended, then the same shall be stated on the said section," &c. *(See TT Plate)* "That where tunnelling, as a substitute for open cutting, or arching as a substitute for solid embankment, be intended, the same shall be marked both on the plan and section." *(See YY on Plate.)* "That it shall not be lawful for the said company to deviate from the levels of the said railway, as referred to the common datum line described on the section so approved of by Parliament, and as marked on the same, to any extent exceeding in any place five feet, or in passing through towns, two feet, without the consent of the owners," &c. "And that no increase in the inclination or gradients of the said railway, as denoted by the said section, shall be made in any place, to an extent exceeding the rate of three feet per mile," &c. It is also enacted, "That it shall not be lawful to diminish the radius of any curve, as described on the plan deposited with the Clerk of the Peace, or principal Sheriff-clerk, unless such radius exceed one mile; nor to diminish it in any such case, so that it shall become less than one mile, nor to diminish any greater radius by more than a quarter of a mile, unless when it exceeds two miles, or by more than half a mile, unless when it exceeds three miles on the said plan." On the plan should be exhibited the height of the several embankments, and the depth of the several cuttings respectively. (*See the dotted lines on the Plan.)* This is called Sectio-Planography.

By consulting the Acts of Parliament relating to the construction of rail-roads, canals, &c. all the information required on such subjects may be learned, by which the engineer will be enabled to comply with the provisions of the "standing orders."

The removal and disposition of the cuttings, to form embankments, so as to produce the greatest economy in labour and expense, is a question of great difficulty, and one demanding a knowledge of analytic science of no ordinary character.

In removing the volume of an excavation to form an embankment, the principle applied in all cases is, "that to make the transportation a minimum between the points from which the earth is taken, and that where it is deposited, the lines passed over by the centres of gravity of all the particles must neither cross each other in a horizontal, nor in a vertical direction."

In forming the excavations, particular care must be taken to form the slopes according to the particular nature of the soil. In cutting through a rock which does not crumble on being exposed to the action of the atmosphere, the sun, or any other natural agent,

the side-slopes might be perpendicu
through a mixture of clay and sand,
compact stony soil, the slopes will
the soil, but will depend on the hei
should have a slope varying from ½
gravelly soils require a slope of 1½ to 1
sures 1½ to 1; the London clay 1 to 1
sometimes slips at 3 to 1; and blue s
times slips at 4 to 1. When stone can be
had, it would be well to build a small wall
at the foot of the slopes, to prevent the part
down the slopes being carried into the side

In order to expose the roadway to the d
ence of the sun, the slopes on the south si
be greater than those on the north side.

Embankments should be made sufficiently
when they shrink, they sometimes become too
and then require an addition to be made to them
is a work of extreme difficulty; these additions, be
are very apt to slip.

Width of ground required for the constructio
a Railway.—The width generally allowed for a dou
line of railway is 15 yards, allowing 2 yards on ea
side for drainage and fencing. The quantity of la
required for this per mile is 5.455 acres; and
1.454545 be multiplied by the number of yards in
perpendicular height, in any cutting or embankment,
of a slope of 2 to 1, the product will give the additional
number of acres per mile forward. By averaging the
width of cuttings, and height of embankments, the
entire length of any line may be estimated.

Let us take a line 100 miles long, 15 yards wide, and averaging in depth of cutting and height of embankment, 8 yards.

First, 5.455 × 100=545.5 acres for roadway, ditching, and fencing; and 8 × 1.454545 × 100=1163.636 acres required for the slopes, at 2 to 1; which added to 545.5, gives 1709.136 acres for the roadway, ditching, fencing, and slopes. In crossing a ravine, it would be necessary to calculate whether or not a viaduct would be cheaper than an embankment; if the making of a viaduct be found cheaper, it is to be preferred to an embankment.

Breadth between rails.—Before the Great Western Railway, the distance between the rails varied from four feet and a half to six feet. Mr. Brunel has made the distance between the rails 7 feet, or 7 feet 2½ inches from centre to centre of rail, and the Irish railway commissioners recommend 6 feet 2 inches; some of the Scotch railway engineers have made the distance between the rails 5½ feet. The breadth then may be said to vary from 4½ to 7 feet. On a broad railway the velocity may be increased without any danger. On a narrow railway, the danger increases with the velocity. In forming embankments, it is sometimes (but very seldom) more economical to procure the materials from some neighbouring locality, than to bring them a considerable distance from the cuttings in the line. In this case the redundant contents, termed spoil bank, of the excavations, are to be disposed of in the cheapest way that the circumstances of the case will permit. In equalizing the excavations and embankments, for the purpose of finding the surface of the rails, the extremities of the line may be a little elevated, and so may the approaches to the principal stations also; as the trains can more easily start from such elevations, and arrive with more security. When a small portion of the excavation or embankment is made, temporary rails should be laid down, for the purpose of facilitating the removal of all the materials from one place to another.

When it becomes necessary that two lines of railway should cross each other on the same level, the point of intersection should, if possible, be on an embankment, but never in deep cutting. When the crossing occurs on an elevated point, no obstacle can impede the sight of the conductors of the trains; but when two roads cross each other, or a curve occurs, in deep cutting, much danger may be apprehended.

Tunnels.—When a hill, town, river, canal, or other obstacle presents itself, so as to make it necessary to form an under-ground passage, the work is generally tedious and expensive, and often attended with extreme difficulty. Tunnels are very common, as a means of conducting canals as well as roads under elevated ground. Among the works of this kind may be mentioned, the canal tunnel under Staindedge, between Manchester and Huddersfield, the length of which is upwards of three miles, and is 660 feet below the surface; the railway tunnel under Liverpool; and the road tunnel under the Thames, which will soon be completed. This, by far the most stupendous work of the kind ever attempted, cannot fail to transmit to the latest posterity, the name of Brunel. This great national undertaking is thirty-eight feet in width, and in the style of a double arcade. It was commenced in 1825, and it is expected to be opened for pedestrians in the beginning of the next year, 1843.

The accompanying figure represents the mouth or entrance of a tunnel, with the approaching slopes of the cutting.

To give additional security and strength, every subterraneous work of this description is built on an inverted arch, and has its vertical sides curved outwards. When a tunnel exceeds a certain length, it must be supplied with shafts, or vertical openings, at equal distances, to allow the foul air to escape. These are termed air-shafts. Vertical pits are sunk above the crown of the tunnel, through which the excavations are taken off. These pits are termed working-shafts. In some soils it is not safe to sink the shafts exactly over the crown of the arch, therefore it is recommended to sink them ten or fifteen feet outside the piers of the arch.

The height and width of a tunnel must depend on the dimensions of the carriages or boats destined to pass through it.

Viaducts.—When a road is to be carried across a deep ravine, it is to be effected either by raising an embankment, or building arches to the proper height. When the road-way requires to be considerably elevated above the bottom of the ravine, it should be conducted across on arches built of stone or brick, being cheaper, more permanent, and ornamental than an embankment.

When a railway is to pass through a town or city, it should, if possible, be carried through a tunnel, or over high arches of masonry, so as not to interfere with the houses or thoroughfares.

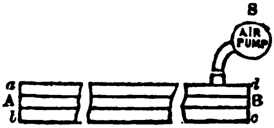
Aqueducts, sometimes termed culverts, should be made under the road, to allow the small water streams to pass from one side to another, wherever necessity arises for such structures. When these are low, and apt to be filled to the crown with water, passing through with great velocity, as on the Dublin and Kingstown Railway, the crown should be supplied with vent-holes, which will, in a great measure, prevent the destruction of the arch by the upward pressure of the fluid. These vent-holes may be seen on the culverts under the Dublin and Kingstown Railway.

ATMOSPHERIC RAILWAY.

Messrs. Clegg and Sumada have invented a railway, on which carriages may be propelled by atmospheric pressure. Midway between the rails of an ordinary railway, lies secured to the sleepers a continuous pipe of suitable diameter; let a piston attached to a carriage for passengers, run in this pipe, and a stationary steam engine exhaust the pipe before it. Now, it is manifest that if the parts of the machinery are sufficiently perfect, the atmospheric pressure on the back of the piston will move the carriage and its load, with a velocity resulting from the difference between that pressure and the resistance to be overcome. No doubt, so far as theory is concerned, this mechanical arrangement is indisputable; but without a practical proof of its working power, few persons could be convinced that the machinery could be made so perfect as to produce the desired effect. The experiments which have been tried, have satisfied such as witnessed them, of the efficiency of the plan on a small scale; and if they prove equally successful on a more extensive scale, the inventors will establish a most important era in the history of railway travelling. The rails and pipes (of half a mile in length,) are laid on an embankment belonging to the West London Railway Company, having an incline of 1 in 115. The pipe is cylindrical, and nine inch internal diameter; the air pump is 37½ inches diameter, and is worked by a stationary steam engine of sixteen horse power. Throughout the entire length of the pipe, there is a slit in its crown, to afford the needful connection between the piston and the carriage. The internal surface of the pipe is coated with tallow, and the piston which passes through it is made air-tight by leather packing. The connection between the piston and the leading carriage of the train is effected by what is termed a coulter, which moves through the slit in the crown of the pipe. "While one set of vertical rollers attached to the piston, at some little distance behind the piston, progressively lift up for the space of a few feet, and another set of rollers, attached to the carriage, close down again, a portion of continuous flexible valve or flap, of peculiar construction, covering the aperture; and it is the very simple, ingenious, and efficient mode of successively opening and closing down, and hermetically sealing this valve, as each train advances and moves on, that constitutes the merit of the invention, and the foundation of the patent: the operation consisting, first, in opening the valve to admit the free admission of the external air, to press on the back of the piston, and produce motion; and then, in effectually closing down and sealing the valve again, so as to leave the pipe in a state to receive the travelling piston of the next train, and ready to be again exhausted of its air."

In practice, stationary engines, of sufficient power, are to be placed at intervals of three miles apart, which will work the railway on either side of the engines, as the case may require.

In the annexed diagram, let *a b c d* be a tube, having a slit AB in its crown, and an air-pump S, the slit being covered with a leather flap, to exclude the atmosphere. Now, if the space from A to B be completely exhausted, it is obvious that the external pressure of the atmosphere on the back of the piston at A, will drive it forward towards B, with a force equal to that impressed, diminished by the resistance to be overcome. When the tube is not completely exhausted, the force of the external atmosphere is diminished by the quantity remaining in the tube. It is therefore of great importance to make the vacuum as complete as possible, and prevent leakage, as when the main pipe is not sufficiently staunch, the leakage imposes additional work on the air-pump, which, too, ought to be free from imperfection or leakage, as any imperfection in this imposes additional work on the stationary steam engine which works it; by which an increased expense is incurred in fuel, and a long time required to extract the air, and create a sufficient vacuum in the main.



In the absence of suitable experiments upon a large scale, it is a matter of some difficulty to compare a railroad on the atmospheric principle with one of the ordinary description, as regards economy.

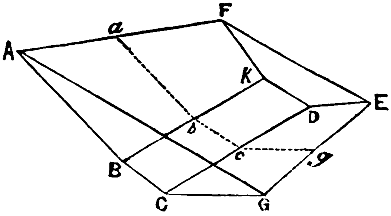
In an enquiry upon this subject, Mr. Bergin, in his pamphlet recently published, very properly observes, that to investigate the "powers absorbed or expended in producing any required exhaustion in the working main, involving, in this part of the enquiry, the discharging power of the air-pump, and the waste of power by the leakage of the whole apparatus." Besides this, it is necessary to ascertain "the expenditure of engine power necessary to maintain any given amount of exhaustion already obtained in the working main." In the notes to Mr. Bergin's pamphlet, may be seen formulas bearing upon this subject, well worthy the attention of persons interested in such matters. His observations on the report of Colonel Smith and Professor Barlow, prove how competent he is, both in theory and practice, to discuss the subject matter of his publication.

Mr. Pim, the talented treasurer of the Dublin and Kingstown Railway Company, has lately published a pamphlet, addressed to the Earl of Ripon, President of the Board of Trade, from which one or two quotations have been taken, and in which he advocates the Atmospheric Railway.

Mr. Pim is known to be a gentleman of singular talent, and of sound and comprehensive views upon all subjects connected with the improvement of the country, so far as regards public works; and the result of the experiments witnessed by him at Wormwood Scrubs, has convinced him of the superiority of the atmospheric system, as compared with the present system in general use, where steam power is employed. We are very happy to hear that, through the exertions of Mr. Pim, this new invention is to get a fair trial, the patentees having agreed to construct a railway from Kingstown to Killiney, a distance of two miles, on which carriages are to be propelled by atmospheric power. On account of all the parties concerned, we anxiously hope that this project may prove successful. As the extension of the Dublin and Kingstown Railway will soon be completed, on the Pneumatic principle, we shall before long have an opportunity of proving all the advantages and disadvantages peculiar to it.

Rule for calculating Excavations and Embankments.—The excavations and embankments on a railway or canal are, in most cases, resolvable into prismoids, whose cubic contents are found by the following rule, for a demonstration of which, see the author's Treatise on Mensuration for the Irish National Schools.

To the areas of each end add four times the mean area, and multiply the sum by one-sixth of the length of the prismoid, for the cubic content. That is, to the area ABCG + area FKDE + 4 times the area $abcg$, multiplied by $\frac{CD}{6}$; or if the bases be dissimilar rectangles, take two corresponding dimensions, and multiply each by the sum of double the other dimension of the same end, and the dimension of the other end corresponding to this last dimension; then multiply the sum of the products by the height, and one-sixth of the last product will be the solidity.



Every cutting and embankment is generally a prismoid. But in deep cutting, where the slopes may stand at different angles of inclination, owing to a variation in the composition of the different strata, each slope must be calculated separately. When a change of slope takes place, a ledge or benching is left when the angle of slope changes. When speaking of slopes, such as 2 to 1, or 3 to 1, or 2 to 3, the base is always first. 2 to 1 signifies, that for every 2 feet base there is 1 foot perpendicular; 2 to 3 means, that for every 2 feet base there are 3 feet perpendicular.

With such valuable assistance as Mr. M'Neil's tables afford, no one would think of calculating earth-work without them. They are not however applicable in every case that may occur.

Examples in Cutting.—1. Suppose the section of a railway cutting had the following dimensions, viz. 20 feet wide at bottom, 24 feet wide at top, and 6 feet deep; required the solid content of 4767 feet, allowing the section to remain uniform for that distance?

$20+24=44$, and $44\div2=22$, mean breadth.

$22\times6=132$; then $132\times4767=629244$ cubic feet, and $629244\div27=23305\frac{1}{3}$ cubic yards. Let us suppose this to be done at 8d. per yard, it would amount to £776 16*s*. $10\frac{2}{3}$*d*.

2. Let us suppose a section of a railway cutting to have the following dimensions, viz. 26 feet wide at bottom, 52 wide at top, and 8 feet deep, the length being 850 feet.

$26+52=78$, $78\div2=39=$mean breadth.

$850\times8=6800$; then, $6800\times39=265200$ cubic feet, $265200\div3=88400$, and $88400\div9=9822\frac{2}{9}$ cubic yards, which, at 6d. a yard for cutting, would amount to £245 11*s*. $1\frac{1}{3}$*d*.

3. Let us suppose the cutting for a railway to have the following dimensions, viz. perpendicular height 20 feet, width at bottom 32 feet, at top 56 feet, and length

76752 feet; what is the expense of cutting, at 6d. per cubic yard; of removing, at 1d. per yard; and of arranging for another purpose, at 2d. per yard.

32=width at bottom.
56=width at top.

$$2\overline{)88}$$

44, mean width; then, $44\times20=880$, and $880\times76752=67541760$ cubic feet.

$67541760\div3=22513920$, and $22513920\div9=2501546\frac{2}{3}$, which, at 6d. per yard, amounts to £62538 13*s*. 4*d*.; at 1d. per yard for removing, amounts to £10423 2*s*. 2$\frac{2}{3}$*d*.; and at 2d. per yard, amounts to £20846 4*s*. 5$\frac{1}{3}$*d*.

Cuttings similar to these very seldom occur in practice. It very rarely happens that a cutting presents the same cross section for any considerable length of the line.

Note.—In the foregoing examples, the two ends are equal, and the height the same throughout, in which case the calculation is very simple; but when the ends are unequal, as in the following examples, the work becomes more difficult.

How many solid yards in a cutting, whose ends are rectangles, the length and breadth of one being 14 and 12 feet, and the corresponding sides of the other 6 and 4 feet, the length of the cutting being 30½ yards.

$\left.\begin{array}{l}7+3=10\\6+2=\ \ 8\end{array}\right\}$ dimensions in the middle.

$10\times8=80$=middle area, and $80\times4=320$=4 times middle area.

$14\times12=168$=area of greater end.

$6\times\ 4=\ \ 24$=area of lesser end; then $320+168+24=512$; then $512\div9=56\frac{8}{9}$ square yards, and $56\frac{8}{9}\times30\frac{1}{2}=1735\frac{1}{9}$ yards.

CANALS.

The first duty that devolves on the engineer, is to make a minute survey of the country through which the canal is to pass. A line of canal does not require such good horizontal levels, or so direct a course, as a railroad. The rises and falls, however, must be within certain limits. When the direct line of a canal is intercepted by a hill, it is sometimes advisable to change the direction, by going round the bottom or bosom of the hill, as the circumstances of the case may require. Abrupt turns should be avoided, if possible.

Having made a survey of the line determined on, the engineer should next take the levels of it, and then prepare a map and section, exhibiting all the objects within the district through which it is to pass; such as rivulets, mill-streams, &c., also the various hills and valleys, with all the undulations of the surface, which will furnish sufficient data to ascertain the number and situation of all the locks required to be erected along the line.

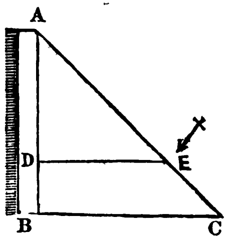
The section of the proposed canal, with the summit-level of the neighbouring hills, lakes, rivers, and streams, will enable the engineer to ascertain the most advisable summit-level of his canal, which must be commanded by so many of these head-waters as are sufficient to supply it with the required quantity of water. The required supply is determined by actually gauging all the waters which command the summit-level of the canal; and if the supply be not found sufficient, the summit-level of the canal must be lowered, or recourse must be had to some artificial means to increase the supply; which may be done by constructing reservoirs to receive all the rain and surface water from the various surrounding eminences. The reservoirs must be so high as that their contents may be drawn into the summit of the canal at pleasure. They should contract towards their lower extremity, so as to require but a short embankment. Great care must be taken that these basins do not leak, and that their embankments be of sufficient dimensions; which last must be regulated by the nature of the materials of which they are composed.

Few superficial observers are aware of the vast quantity of water that may be collected into a reservoir judiciously situated. Mr. Longbottom, who obtained a patent for the construction of reservoirs, states that 3.33 cubical feet of rain-water fall upon one superficial foot of land, exclusive of exhalation; making the quantity which falls upon one statute acre about 14505480 cubical feet, in the course of one year.

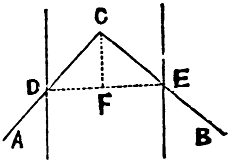
Reservoirs may often be replenished, by taking advantage of high floods in the neighbouring rivers, which may sometimes be easily diverted from their wonted course, at a certain elevation. As an instance of the quantity of water that might sometimes be collected, by taking advantage of the overflowing of a river in time of flood, the author calculated that on the 20th of June, 1839, 686228 gallons of water, per minute, must have flowed over the face of the neighbouring country, in consequence of a breach having been effected by the flood betwixt the Railway and Ball's-bridge, on the river Dodder, near Dublin. And therefore, if the flood had continued at the same altitude for one hour, the quantity escaping through the breach, during that time, would be sufficient to cover 151 acres one foot deep, or 75½ acres two feet deep. If this flood had continued but for a few hours, the quantity of water that might have been reserved for the purpose of feeding a canal, would be very considerable. In countries where water is scarce, various means have been tried to supply their canals with water.

Horizontal Thrust.—When water is confined in a canal or basin by a wall or embankment, the dimensions of the barrier must increase in proportion to its depth. The resistance which such a barrier is capable of making, when pressed by a fluid, depends much upon the weight and adhesion of the materials.

Let us suppose AB to be the height of a wall, and its density to be three times that of water, as AB to BC; then the line AC will represent the proper slope. When the dyke AB is composed of stone or brick, the practice of the best engineers is to make the base BC equal to the height AB; and when it consists of earth, the base BC is generally one half more than AB. When the embankment is composed of earth, its side must form an inclined plane, not exceeding 35 degrees. When the inside face is more perpendicular than this, the softened parts or washings slide down. The outside, being more solid, may be much steeper.



The construction of Flood-gates or Locks.—By a series of locks on a canal, a boat is enabled to rise from a lower level to a higher, and fall from a higher level to a lower. A boat being thus capable of changing its level, can proceed up or down at pleasure. The angle at which the flood-gates are made to shut, is not invariably the same, being sometimes very obtuse, and at other times right.



Where such a diversity of forms exists, it may be well to investigate the angle at which they ought to close. In the first place, when the angle is very acute, they sustain too great a pressure, and yet close very feebly. Let DC and EC represent the flood-gates of a canal, which are opened and closed in the usual way, by means of the arms AD and BE. Now, when the gate is shut, DC is pressed at right angles by the water, with a force varying as DC itself. But as DC turns upon a hinge at D, it is manifest from the property of the lever, that there is exerted a perpendicular effort at the end C, that varies as DC^2. The thrust thence produced in the direction DE will be as DC×CF, and will encounter an equal and opposite thrust from the gate EC. These two forces constitute the power which closes the gates. The force with which the gates are made to cohere, thus increasing with DC and CF, must augment rapidly when the angles EDC and DEC are enlarged, or their mutual inclination, DCE, becomes diminished. When the angle DCE becomes very obtuse, those conjoined gates would occasion a great thrust against the side walls of the canal. The thrust in the direction CD might be shewn to be $DC^2 \times DF \div CF$. From this it will be easy to determine the angle DCE, which, with the centres of the flood-gates, suffers the smallest strain. For DF being constant,

$DC^2 \div CF$ must be a minimum. But this quantity is evidently the diameter of a circle circumscribing the triangle DCE; and since the least circle is that described about the point C, the angle DCE, at which the gates lock, should be a right angle. This is, in substance, Sir John Leslie's proof. The general practice however is to make the angle at which the gates meet, a very obtuse angle.

The form of the locks should approach as nearly as possible to the figure of the boats which are to navigate the canal. The width should not exceed that of the boat by more than is barely sufficient to work the gates. They should consume a minimum quantity of water, and be capable of being filled and emptied in the shortest possible time. To answer all these conditions, the locks must be rectangles, the length, breadth, and depth of which must entirely depend on the dimensions of the boats, which are generally long and narrow, with flat bottoms. Boats of this shape are easily drawn, and require but a small quantity of water.

Slopes.—When the banks of a river or canal are not formed with proper slopes, they do not retain their form. That they may do so, Mr. Eytilweir recommends that the breadth at bottom should be $\frac{2}{3}$ of the depth, and at the surface $\frac{10}{3}$. The area of such a section is twice the square of the depth, and the hydraulic mean depth $\frac{2}{3}$ of the actual depth.

The mean hydraulic depth is the depth a river would have if it flowed in a new channel, whose sides were vertical, and whose bottom was flat, and equal in breadth to the bottom and sides of its real channel. This depth is found by dividing the area of the transverse section by the breadth of the bottom of the new channel.

The construction of locks or basins, lined with walls of solid masonry, requires all the skill and ingenuity of him who superintends the works. They are built where the ground is hilly, and enable boats to ascend or descend. If we suppose a declivity of 10 feet in a length of 150 feet of ground; in this case a lock or basin must be constructed, with one flood-gate, which, when closed, and the basin filled with water from above, permits the boat to pass along the upper channel of the canal. If we suppose a fall of 17 feet, there must be two locks; and a fall of 26 feet would require three locks, each having a fall of 8 feet 8 inches. Divide the fall by the height of the lock, and the quotient gives the number of locks.

The principle on which a boat is raised from a lower level to a higher, and lowered from a higher level to a lower, is very easily understood. In ascending, the gates are closed behind the boat, and a lateral or superior sluice opened, which allows the water to rush from above into the lock, which it soon fills, lifting the boat to the level of the upper reach of the canal. The operation is repeated at every successive lock. In descending, the water inclosed in the series of locks is allowed to flow out by reversing the above process, by which the boat descends from a higher to a lower level.

The engineer, in cutting a canal, must keep one great principle in view; namely, that no farther excavation is required, than what is sufficient to hold the water at a given depth and breadth. But as the modern practice is to raise a bank on either side with the stuff excavated, it evidently follows that the level of the surface of the canal may thus be raised above the natural surface of the land; by which a part of the excavation is saved.

When the excavation, with the stuff excavated placed on either side of the canal, is just sufficient to hold the surface of the water at the required height, the operation is called level cutting. When the ground through which the canal runs has a declivity, the upper side may require little or none of the stuff excavated, while the lower side may require much or all; this case is called side or oblique cutting. The slope of the cut which is made in the hill, is the same as the exterior of the canal bank. These two lines in the section are parallel to each other. Now, if we conceive a point in the section, through which, if any line be drawn, representing the surface of the ground in any case, (which line we shall call the line of cutting,) the portion of the section, thereby exhibited as excavation, will always be equal to that exhibited as embankment. This point is called the centre of cutting.

Before we proceed farther, the following maxims are necessary:

The depth of the water-way should exceed the draft of the boats by at least eighteen inches. The width of the water-way should be sufficient to allow two boats to pass each other. The thickness of the embankment at top should be from four to six feet. The tow-path for horses should be at least twelve feet wide, and the foot-path for passengers, six feet wide. The height of the top of these paths should not be less than from one to two feet above the surface of the water; nor should they be higher than four feet, if the nature of the ground would admit of it.

When the situation of the horses is much higher than the boats, the line of traction is unfavourably placed, imposing upon the animals the necessity of increased muscular exertion in towing. The surface of the tow-path should incline outwards, to give the horses a firmer footing, and to convey off the surface-water.

The pressure of any fluid being proportional to the depth below the surface, the strain borne by a sluice on the side of a canal, must increase uniformly from top to bottom. Therefore, in making a flood-gate, it should not be of uniform strength from top to bottom.

In the first figure, if BC be made to represent the pressure at the point B, then DE will represent the amount of pressure at D. Also the area of the triangle ABC will represent the whole pressure against the entire of the upright side AB, which is but half the pressure on the bottom of the same area as the side.

Centre of pressure.—The centre of pressure is that point of any plane, to which, if the total pressure were applied, its effect upon the plane would be the same as when it was distributed equally over the whole; therefore, if at this point a force were applied equal to the total pressure, but in an opposite direction, both forces would balance, and the plane would be restrained from turning to either side. The centre of pressure is not at the middle of the plane pressed, but at one-third of the entire altitude, measuring from the bottom. Hence, if more strength be wanted, the additional prop must be applied to this point. A knowledge of this fact is of the utmost importance to the engineer employed in works in which the pressure of fluids is to be considered.

From what has been said, barrels and vats should be more strongly hooped at the bottom than at the top; and so should flood-gates and lock-gates have heavier fastenings at the bottom than at the top. It has been said that the centre of pressure of a plane, reaching to the surface of the fluid whose pressure it sustains, is at a distance from its lower extremity equal to one-third of its whole length, (the plane being supposed to be a rectangle,) and that a single force applied at that distance, and in the middle of its breadth, would hold the plane at rest. The plane will also be kept at rest by the application of a rod, either longitudinally or laterally, at that point. Now, as a rectangular sluice or flood-gate might be held in its place by the pressure of a single force against it, or by the application of a rod across it at one-third of its height, counting from the bottom, it is manifest, if the gate be made to turn upon a horizontal axis, passing across it at that distance from the bottom, it would keep itself closed, notwithstanding its freedom of motion about that axis. Hence it follows, that if the reservoir contained too much water, the centre of pressure will move upward, and therefore the gate will be forced open, by which the surface of the water will fall to its proper level, and the gate, by its own pressure, would close itself.

The point at which the centre of pressure is placed being at one-third of the whole height of the gate, it follows that its beams and hinges should not be placed at equal distances from its top and bottom, but at equal distances above and below the centre of pressure. It also follows that a single hoop is sufficient to keep the staves of a barrel together, if placed at two-thirds the depth of the contained fluid. This should be particularly attended to in the construction of lock-gates, or vessels which are to bear the pressure of fluids.

As we are upon this subject, it may not be useless, though perhaps out of place, to introduce a subject connected with the economy of canals. Some time ago, it was the practice to travel on canals with a speed so very slow, as to deter persons, with whom time was an object of primary consideration, from performing any journey by them. This slow rate of travelling was owing to a general opinion then prevailing, that a greater speed would increase the resistance so much, as to demand a power to overcome it, which it would not be wise or economical to expend. But the recent experiments of Messrs. M'Neil, Grahame, Telford, Cubit, and Russell, prove that the resistance of fluids (as in the case of a boat on a canal) does not increase in the duplicate ratio of the velocity. Hence it is that some canal-boats travel now at the rate of twelve miles an hour. As long as the boat remains immersed in the water to the same water line, we do not doubt but that the resistance increases, perhaps as the square of the velocity; but when the velocity is increased beyond a certain point, the boat emerges out of the water, and skims near the surface; and the greater the velocity, the nearer the surface will she move; and therefore the resistance cannot increase considerably: as when she rises higher she presents a less cross-section to the action of the resisting fluid. Up to four and a half miles an hour, a light boat is raised very little, if any at all, out of the water; and therefore the resistance is found to agree pretty nearly with the theory, that it increases in the duplicate ratio of the velocity. But when we compare the resistance experienced by a boat moving very slowly, with that experienced by her when moving very rapidly through the water, we shall find that instead of meeting with increased resistance, in the duplicate ratio of the velocity, she experiences a resistance falling far short of that given by this law. Want of sufficient data, founded upon repeated experiments, often leads to erroneous results. Mr. M'Neil states, that a horse, on a canal, can draw 18 tons per day, while Mr. Wood states 2.4 tons, and Mr. Telford 6.6 tons to be the work of a horse under similar circumstances.

From the experiments made some time ago on the Forth and Clyde Canal, under the direction of Mr. M'Neil, it was ascertained that the wave of the canal, on account of its great depth, travels at the rate of eleven or twelve miles an hour; and, therefore, in order to ride on the wave, it would be necessary to draw the boat at the rate of fourteen or fifteen miles an hour—a speed not in the power of a horse dragging any load. But having an idea before that at these high velocities, the destructive surges usual at velocities of eight or nine miles an hour, would altogether disappear, and the boat ride on a smooth, undulating wave, exciting little commotion in the waters of the canal; a locomotive engine, running along the bank of the canal, drew a boat full of passengers, at the rate of more than nineteen miles per hour, which rapid speed caused little or no commotion in the waters of the canal; and thus proving.

beyond any doubt, the truth of what had been predicted. When the velocity was diminished below that of the wave, the consequence which followed was a high and powerful wave at the bow, with a foaming surge at the stern, and a great swell towards the banks.

The substitution of iron boats, of a peculiar construction, drawn by a locomotive engine, running with high velocities, on a proper rail-road constructed on the bank, would soon bring canal traffic into competition with that of railways. For the transmission of heavy goods, water carriage, as here described, would be found more economical than any other placed at our disposal by the agency of steam. But where great speed, and a consequent saving of time, form principal elements in the economy of travelling, rail-roads claim the preference.

If some means were contrived to prevent a recurrence of those fatal accidents which so frequently happen on rail-roads, principally through the neglect of the enginemen, railway travelling could not be equalled by any other means within the scope of human invention. We have seen and heard of numerous contrivances to prevent accidents on rail-roads, but none of them has proved successful in accomplishing what is still felt to be the greatest desideratum in that mode of travelling.

Mr. Russell says, that the velocity of the wave down to a depth of four feet, making allowance for the sloping sides of the canal, is seven miles an hour; and therefore the horses must travel at a greater speed than this to keep the boat on the top of the canal wave. He also says, if the depth be seven feet, the velocity of the wave will be about nine miles an hour, which is a speed impossible for a horse to keep up for any length of time. When the boat travels at a less speed than the wave, it is a disadvantage.

It has been stated before, that the engineer, in laying out the dimensions of his canal, must be guided by the description of boats intended to navigate it. Some of the canals in Holland are from fifty to seventy feet wide, and sometimes more; while with us thirty feet is considered a good width at the summit level, and in some cases the width varies as low as eight feet. The average depth of the English canals is between four and eight feet, with the banks one foot higher than the surface of the water. In cutting a canal, the engineer should commence at some point from which the water may flow, by which a considerable part of the expense incurred in keeping the works free from water, is saved. When the work proceeds from a higher point to a lower, the water follows the workmen, and the pump must be constantly at work. We have seen a canal mismanaged in this way, by which the pumping of the water created a very considerable item in the expense.

As wet weather may delay the progress of the works, and destroy such of them as may have been recently erected, it would be advisable to commence operations as early in the spring as possible; and among the first works to be done, should be the foundations for bridges, locks, and basins; also the culverts and drains which are to pass under the canal.

Puddle-lining should be applied to such parts of the canal-banks as are composed of materials which allow the water to pass through them too freely. A light loam, mixed with silecious particles, in the proportion of two to one, is considered to make the best puddle.

Among the many difficulties which the engineer is to encounter, to prevent leakage is not the least. His care should therefore be directed in a special manner to the best mode of puddle-lining his canal, so as to prevent the possibility of the water percolating through the banks.

To the Dutch is due the credit of puddling, without which their canals, being so very high above the natural surface of the ground, would always leak. In Holland it is not uncommon to see canal embankments twelve feet high or more, the water reaching within two feet of the top.

When the traffic upon a canal is very considerable, it must be furnished with passing places, where boats may rest without impeding the navigation. These are generally situated in some low situation, not far from the locks.

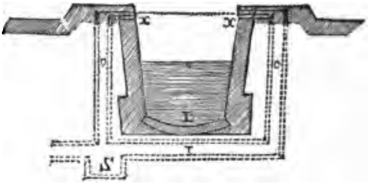
It has been stated before, that wherever a deficiency of water exists, it must be supplied by reservoirs, formed for the purpose of supplying the canal whenever it falls short of the necessary quantity. The banks of these reservoirs must be puddle-lined, to prevent the water from passing through.

The slope is generally two feet base to one foot perpendicular, and in some clays the base is as much as three feet to one perpendicular. When too great a quantity of water flows into the reservoirs, which might often happen in times of high floods, the redundant quantity must be readily disposed of by means of weirs, or *tumbling bays*, constructed in such situations as are best calculated to give it a ready exit.

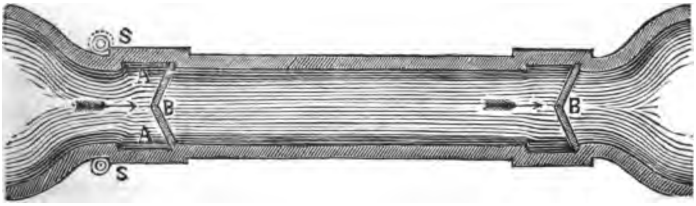
These tumbling bays are syphons constructed in the embankment of the reservoir, and made of strong masonry properly cemented, to which a horizontal communication is opened by the side of the embankment of the reservoir.

The bottom of the syphon should enter a culvert or drain, which should have a tolerable slope to allow the free discharge of the water.

In the formation of locks, the utmost skill and attention of the engineer are required. The flooring of the lock chamber must be an inverted arch, built of the best hewn stone, slightly curved, and well jointed. The figure in the margin is a section of a lock, in which is the inverted arch or flooring L. The abutments, or bottom of the side walls of the chamber, ought to be twice as thick as the top, and should slope, batter, or rack, as they ascend. The side walls must be made water-tight, and ought to curve in their height, by which they would be rendered more strong.



In building the piers, a recess should be left for the reception of each gate, when open, as at A. The superfluous water makes its escape through two aper-



tures made in the side walls of the wings, as is represented on the accompanying plan by the small circles at S, and on the preceding section by the narrow passage at *o*, *o*. The water escaping through these apertures should enter the lock through a bent culvert. The gates at their bottom should be well supported by the sills built across the extremities of the chambers, and forming an angle equal to that at which the gates are made to shut, which is generally obtuse, being found the most convenient, though, as has been shewn before, not the strongest.

In Ireland, very little wood is used in the construction of locks, the platform for the gates, as well as the sills, being made of hewn stone; but in other countries, where good stone and mortar are not so easily procured, the platform on which the gates traverse, is usually made of timber.

A strong floor of plank is spiked or tree-nailed down on transverse beams, which are laid across the lock. In very large locks, two rows of whole baulk in thickness are laid close together over the whole floor, well bedded in a mass of water-tight rubble masonry, and where there is a bad foundation, it must be piled. A row of grooved sheet piles is driven across the lock, at the upper and lower end of this platform, and then the floor is well staunched to prevent leakage. The sill of the lower gate is placed on this platform, having the angle or curve of the lock-gates. The platform of the upper gates is constructed exactly in a similar manner. The side walls are made with a recess on each side, to allow the gate to fall back, so as not to obstruct the passage of the vessels.

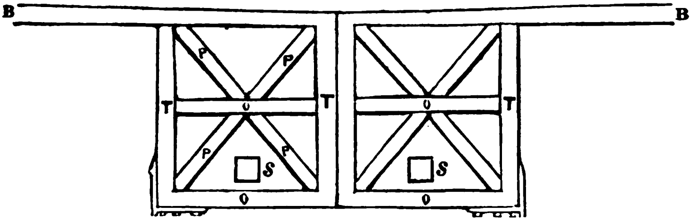
The paddle-holes are sometimes united at the back of the breast-wall, and discharge themselves through that into the lock, and sometimes they enter the lock separately in each side. The paddle itself is usually a square of wood, which is made to slide up and down in a rabbited frame of timber, fixed in the stone mouth of the paddle-hole, by means of a crank and pinion, working into a toothed rack, which is fixed on a handle, rising from the paddle to the top of the bank or gate. This office is sometimes performed by means of a screw, which, acting upon the paddles, makes it turn on its axis like a scouring-gate.

The waste water, passing through the side culverts, escapes below the tail of the lock, but when this water is required to fill the lock, its passage through the side culvert is prevented by closing the mouth of the passage.

In making the locks, it is desirable to have them all of the same size, and as small as the boats intended to pass through them will permit. By attending to this principle, the loss of water at each lock will be equal and proportionally small, in which case the anticipated supply may be easily calculated.

Mr. Fulton mentions that a twenty-five ton boat consumes 163 tuns of water in ascending a lock with a rise of eight feet, and 103 tuns in descending the same, making a difference in the loss of 60 tuns—a thing not very obvious, the same space being filled in ascending and descending. The syphons *o o* must be made of well jointed stone, or cast iron, and the culvert T should be furnished with a cess-pool S, to receive any matter carried by the water, to prevent its overflowing or stopping up; the apertures *xx*, communicate with the syphons *o o*, and are made a few inches below the top-water level.

The accompanying figure represents a pair of gates, the different parts of which are known by the following names: B, B are called the balance beams; *o, o, o, o* the rails; T, T, the vertical stiles; P, P, the braces; *s, s*, the paddle-holes. This framed work is covered



by oak planking, grooved into the bottom rail and the balance beam. The entire should be sufficiently strong to resist any force that might oppose it. Additional strength might be gained by curving the gates, directing the convex side to oppose the pressure; but to give them this form would be attended with considerable expense and loss of material, which perhaps would more than counter-balance any advantage that might be derived from its adoption. The paddle-holes *s, s*, are generally twenty inches square, to which small doors are fitted. These are useful in preventing too sudden a gush of water into the locks, which might prove fatal to the boats. In long lines of canal, with great traffic, the loss of water (on account of the gates being repeatedly opened in a short space of time,) may render the upper reaches too shallow.

To remedy this inconvenience, many expedients have been resorted to; and among the best of them may be mentioned the formation of side ponds on each side of the chamber of the lock. They consist of a number of projecting cisterns, varying gradually in their elevation, beginning a short distance from the bottom, at the lower end of the lock, and stepping up to the head of the lock, all being provided with paddle doors. These cisterns are made so capacious as to contain all the water that passes the upper gates, during the ascent or descent of a boat through the lock.

When the chamber of the lock is full, the highest paddle doors are opened, and the water empties itself into the cisterns right and left; the same is done with all the descending cisterns, till the whole are full, taking care to shut the doors of the cisterns as the water retires in the lock; and this is done till the chamber of the lock is so emptied as to allow its lower gates being opened.

By this plan, very little water is consumed during the passage of a boat, except what is just sufficient to keep the boat afloat, and level with the lower level of the water of the canal.

A patent was taken out for the construction of side ponds in 1791, by Mr. Playfair, an eminet architect, the specification of which may be seen in the Repertory of Arts, vol. iii. In the patent, the application is supposed to be made under the following circumstances: "A lock is supposed to be constructed twelve feet deep, sixty feet long, and six feet wide: and it is calculated that the quantity of water required to fill such a lock, to enable it to pass a boat, is 4320 cubic feet; and in ascertaining what water may be necessary for supplying the canal, allowing for waste by evaporation and soakage, it is found (according to the number of boats that may be expected to pass,) that there will not be above 800 cubic feet for each; and hence, it will be necessary to save five-sixths of the whole; to do which, ten cisterns are directed to be made, each of which must be one foot deep, and each have a surface of 360 feet superficial. The aperture or entrance to the lowest cistern must be one foot above the level of the water in the lower part of the canal, and eleven feet under the level of the high water; the second, two feet above the level of low water; and the third, three feet, and so on."

We have thought it necessary to quote so much of the patentee's specification, to illustrate the application of side ponds; and its utility, when there is not an abundant supply of water, is at once apparent. On other canals, where a deficiency of water is anticipated, the practice is to collect the waste water of the leakage into reservoirs, from which it is brought back to the canal by pumps, worked by a steam engine.

In calculating the quantity of water expended in a series of locks, the prism of draught must be taken into account. This prism of draught is the quantity of water required to float the boat in the lock, when the preceding quantity is drawn off; and is manifestly equal in depth to the water in the reaches, unless it were considered advisable to make it just sufficient for the draught of the boat, by which a small quantity of water might be saved.

This problem divides itself into two distinct cases—the one where both the prism of lift and that of draught are drawn off for the passage of a boat; and the other where the prisms of draughts are always retained in the locks.

Let us suppose a case in which there is a flight of locks on each side of the summit-level, to connect it with the two next lower reaches.

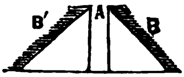
In the first instance, a boat arriving at the foot of the flight, finds all the locks of the flight empty, except the lowest, which of course must contain a prism of draught to float the boat in. In this case, all the locks in the flight must be filled from the summit-level, which will require as many prisms of lift as there are locks, and as many prisms of draught as there are locks, minus one, in order to enable the boat to ascend to the upper level. Therefore, putting L for the prism of lift, and D for the prism of draught, and n for the number of locks in the flight, the quantity of water required for the ascent of the boat will be $n\text{L}+(n-1)\,\text{D}$.

Now, in descending on the opposite side, the boat will require a prism of lift and one of draught at the first lock; but to enter the second, another prism of draught in addition will be required, which will take it through all the remaining locks of the flight. All this quantity will be $\text{L}+2\text{D}$, and, therefore, the entire expenditure for the passage of the boat will be $(n+1)\,\text{L}+(n+1)\text{D}$.

We might easily find expressions for any number of boats passing or repassing, giving the expenditure of water for each particular case.

It is deemed unnecessary to pursue the subject any further, it being more a subject of theoretical speculation, than one of real practical use.

Dams.—Dams are strong barriers, to prevent the



escape of water. They are variously constructed. In some cases they are entirely of earth, in others entirely of masonry, and in others of earth packed between parallel walls of stone.

Nothing requires more caution in its construction than dams, as, if not well made, they are very apt to sink. When they consist entirely of earth, as they generally do, a wide trench should be made to form the foundation; then the earth should be spread on, in thin layers not exceeding one foot in thickness, and firmly rammed. Sometimes a stratum of clay puddling is placed in the centre of the dam, reaching from the top to three or four feet below the base.

The slope next the reservoir should be greater than that at the reverse side. The reservoir side of the slope should be faced with stone, in case the ripple on the surface of the water was likely to injure it. The last figure represents a dam or embankment, with a wall of puddling in the centre at A. The slope B is on the land side, and B′ on the water side. There are few things connected with the works of a canal that require more care than the making of barriers, either for the purpose of confining the water in the canal, or of securing it in reservoirs for the occasional supply of the line in dry weather.

Aqueducts.—When a canal has to pass over a river or a deep ravine, it is effected by means of an aqueduct. The Romans invariably conveyed water in this way for the use of their baths and fountains, but being restricted to this use alone, their aqueducts were only long, narrow walls of adequate height, with an open space which answered for the passage of the water through them.

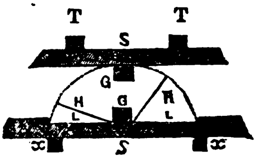
Being ignorant of the property of fluids, discovered by Galileo, namely, that water rises in pipes to its own level, the Romans were obliged to have recourse to aqueducts, supported by arches of solid masonry, built in the most substantial manner, but at enormous expense to the public. The aqueduct at Chapanost, near Lyons, rests upon arches, on the top of which is a narrow channel for the water, arched over at top. This water-passage is six feet high, and three feet wide, lined inside with strong cement about six inches in thickness.

The construction of an aqueduct bridge requires no more skill than is necessary in the erection of an ordinary one, or a viaduct, except in giving to the roadway water-tight qualities.

Aqueducts are sometimes formed of cast iron, with stone piers and abutments. Every aqueduct should be provided with stop-gates, as well as syphons to drain off the water in case of accidents or repairs.

Tunnels are sometimes necessary to convey canals through ridges of high mountains. They are similar to those subterraneous passages now so common upon rail-roads, which serve to connect two points otherwise inaccessible, except by circuitous routes. Tunnels for the purposes of a canal are to be arched under and over, as for a rail-road, the side walls are to be curved, which gives them more strength, the pressure being applied to the convex side. They should be supplied with a horse-path, elevated a little above the surface of the water, which will save the disagreeable trouble of dragging the boat through by manual labour. See the article on tunnels for rail-roads.

Safety-gates are among the expedients made use of for supporting the water in a canal, against accidents to its embankments, and other unforeseen events. By means of safety-gates, the progress of the water is arrested in a long line of canal, wherever the embankments exhibit symptoms of weakness. The accompanying figure is the plan of a safety-gate, in which *s*, *s* are strong walls of masonry or brick-work, built opposite each other on the banks of the canal; T T, x x, are piers to strengthen the extremities of the walls; G G are projections to stop and hinge the gates to; L L are recesses to admit the gates to lie flush with the wall; H is the safety-gate. The plan shews two safety-gates, one to stop the water in the upper, and the other in the lower reach of the canal, according as it may require repairs above or below, one gate not being sufficient for the purpose.



Basins are constructed in or near all towns to which the canal has any communication, in order to afford easy means to boats for loading and unloading. Their dimensions depend on the number of boats likely to trade with the town in or near which they are built. Sufficient space must be allowed on the margin of the basin, for the necessary ware-houses, toll-houses, cranes, and vehicles employed to convey goods of every description to and from the boats.

Broad and convenient approaches should be formed to the basin, for the use of carts employed in the traffic.

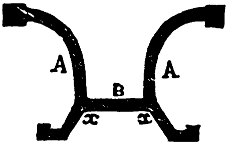
Basins should be built in the most substantial manner; the embankments being level with the wharfs, and about one foot higher than top-water level; and faced by strong walls of masonry, coped with large blocks of granite, or any other durable stone easily obtained. If the foundation be not good, it should be piled. The walls should be of great thickness at the bottom, racking back on their outside, and battering over on their insides.

In building the facing walls, however, a few inches curvature, producing a swell internally in their height, would add much to their strength in resisting pressure. To prevent the boats from striking against the sides of the basin, guard-rails should be fixed against them. These consist of a series of strong piles of oak, or other suitable timber, driven into the bottom of the basin, slanting towards the sides, and at such distances from one another as the security of the walls may require. These are sometimes connected at their top by broad planks of oak, which are bolted to them with strong iron bolts.

A basin should always be provided with a waste-gate, syphon, or weir, the duty of which is to discharge the water flowing into it from the upper reaches of the canal, by waste of lockage, &c. This water discharged by means of a waste-weir, should be conducted through culverts to some convenient place. These culverts should have cess-pools, to receive any solid or other matter floated into them, and should be built in the very best and most substantial manner, as otherwise they might be in danger of being blown up by the pressure of the water. Some basins are furnished with waste-gates, to prevent their overflowing.

The accompanying figure represents the waste-gate at Oxford, on the Oxford Canal. In this figure the walls A, A, are splayed off at the embankments of the canal approaching the basin, terminating in a circular form at their opposite ends. A rebate is left in the masonry at *x*, *x*, where the gates are hung. These gates have no paddles.

Waste-gate.



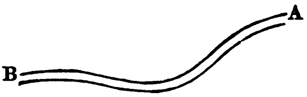
Though the ancients were well aware of the use of canals, it is only to modern science we are indebted for the improvements in that, as well as in many other departments of engineering. The ancients used rolling bridges to draw their boats over these inclined planes, which connect one reach of a canal with another; and the Chinese have no better contrivance to effect the same purpose up to the present time, being totally unacquainted with the use of sluices.

When rivers are small, and the navigation not of sufficient extent to defray the expense of locks and sluices, the Dutch and Flemings make use of these rolling-bridges. To prevent friction, the boats pass over these rollers, which are fixed on these planes, in the neighbourhood of which is generally built a saw-mill, a flax-mill, or a flour-mill, which is made to answer a double purpose, by applying the machinery to the drawing of the boats over the rollers, as well as to the sawing of wood, the dressing of flax, or the grinding of corn.

Mr. Fulton describes two or three methods by which boats may be passed from one horizontal plane to another. The one he terms a perpendicular lift, and the others a single and double inclined plane. A description of the machinery, and the method employed to effect the passage, may be seen in Mr. Fulton's work on inland navigation. Any of these, however, is many degrees inferior to that at present employed in England, Scotland, and Ireland, where locks and sluices are invariably used, as being more convenient and expeditious.

Having shewn the method of calculating the contents of cuttings and embankments, in the article devoted to the construction of rail-roads, it is not deemed necessary to add more on the subject in this place.

Culverts.—When streams of water intersect the line of the canal, the manner in which they are to be disposed of will depend much on the character of their current, their size, and their relative elevation as compared with the canal. When small rivulets lie lower than the canal, they pass under it through culverts built for the purpose. When the rivulet and canal lie nearly on the same level, the culvert must be built in the form of an inverted syphon, similar to the figure in the margin. Culverts of this description must be built in the best manner, in order to resist the upward pressure, which often exerts a destructive influence, by forcing up the crown of the arch.



When, in this last case, the water of the rivulet moves gently, it may be drawn into the canal, taking proper care that the point at which the feeder enters the canal be supplied with works, by which the water may be either received or shut off at pleasure, in any quantity that may be thought necessary. This is effected by making a cut through the sides of the canal, which is faced and bottomed with solid masonry, laid in hydraulic mortar. To this cut is fitted a slide-gate, which is worked up and down through grooves made in the side-walls, by means of rack and pinion-work. When a feeder enters a canal in this manner, it deposits more or less sediment, which, if allowed to enter the canal, would choke it up; therefore, a basin or reservoir should be made near the canal, to receive the water of the feeder before it enters the canal.

When a canal is crossed by a torrent which brings down quantities of sand, mud, &c., works must be erected over the canal, through which the torrent is conveyed.

In the case where the stream glides gently, the stream being nearly on a level with the canal, one end, A, of the inverted syphon must be something higher than the other end B, otherwise the water will lodge in it. When the water of the stream is impregnated with impurities, all must be deposited in a reservoir near the canal, before the limpid stream is allowed to enter the inverted syphon. If the water charged with every description of sedimentary matter were to enter the syphon, it would soon choke up.

The engineer cannot be too cautious in guarding against the many casualties which may possibly arise in the construction of a canal, which involves numerous considerations, requiring an extensive knowledge of science, without which serious mistakes may be committed.

In America, it is a common practice to build the locks of wood, which, in a new country where wood is abundant, is economical; as in proportion to the advancement in trade, locks of greater dimensions, and of more substantial materials, may be substituted for cheap and temporary works, without the sacrifice of expensive or substantial masonry. Another considerable advantage is gained by building locks, in the first instance, of this cheap and abundant material, namely, that the conversion of a boat canal into that of a ship canal is effected at once, without the least scruple; whereas, if the works were of a more expensive and substantial character, the change could not take place, without at least feeling mortified at the idea of being obliged to sacrifice such works; and this feeling operating, very naturally prevents improvement keeping pace with the growing necessities of the times.

Wood is used, not only in the construction of locks, in America, but is also employed in the formation of aqueducts crossing ravines or rivers. Aqueducts are formed of large wooden troughs, resting sometimes on stone pillars, and often on the stumps of trees cut to the proper height. This last contrivance answers very well for some time, and is attended with little or no expense. It is of sufficient duration to create a trade demanding more substantial and expensive works, when the country can best afford to execute them.

The navigation of the North American canals is suspended, and the water withdrawn from them, during the winter season, on account of the intense frost. Were the water left in the canals during the winter months, the expansion of the ice would tear the works asunder, which on the return of fine weather would require to be staunched and repaired, before they could be employed again for the purposes of navigation.

A most astonishing feature in the American canals is their great length, as compared with those of the old world. The Languedoc Canal, the longest in Europe, is only 148 miles, while the Erie Canal is 363 miles in length. The cross-sectional area, however, of the American canals, is not so great as that of some European canals. The North Holland Ship Canal measures 124 feet 6 inches at the water line, and 56 feet at the bottom, with a depth of water of 21 feet, being sufficiently broad to allow large vessels to pass each other in perfect safety. This remarkable canal is nearly 50 miles long.

No country in the world affords such an extent of inland communication by water as America; the extraordinary distance of 2702 miles being entirely performed by means of water communication; 672 miles of which being canal, and the remaining 2030 miles, lake and river.

In America there are two kinds of works employed in forming the inland lines of water communication. These are called slackwater navigation and canals. Canals are much more expensive in their construction than the slackwater navigation, which consists in the improvement of a river by erecting dams or mounds in the streams, by which the depth of the water is increased to a considerable distance up the river, where the fall is not very great. By this cheap and simple contrivance, a river of inconsiderable depth may often be converted into a spacious navigable canal.

That part of the river Suir, between Carrick-on-Suir and Clonmel, might be much improved by erecting dams near the shallows, which would have the effect of deepening the water at these places, and rendering the whole distance perfectly navigable. A similar contrivance would render many parts of other rivers in Ireland navigable. The dams constructed to confine the water, are passed by means of locks, similar to those used in canals. The tow-path is formed along the margin of the river.

The river Laune, which takes its rise in the Lake of Killarney, and empties itself below the town of Kilorglin into Castlemain Bay, may be rendered navigable upon this plan, at a small expense; by which the town of Killarney, and the entire district on either side of the river, would be much benefited. If the rendering of this river navigable presented no other advantage than the facility it would afford of bringing sea-sand by water to all the adjoining districts, as far as the lake, it would be no small recompense. From the quantity of broken shells mixed with the sand, it would prove highly useful to the land, either in a state of tillage or pasture.

The river Fergus might be made navigable to the town of Ennis, for vessels of tolerable burden, by blasting the rock at Clare Castle, and confining the water. The outlay required for the improvement of this river would be but small, when compared with the incalculable benefit.

When the erection of dams for slack-water navigation raises the water over the bank, it must be prevented from overflowing, by embankments, constructed in such situations as are too low. When such embankments are necessary, the outlay for their construction should be compared with the sum it would take to make the river navigable by deepening its bed, and the preference given to that plan requiring in its execution the smallest outlay, the result in both cases being equal.

The town of Bandon would be greatly benefited by rendering the river, from that to the village of Innisshannon, navigable. This would afford water communication with Cork, Kinsale, and other maritime towns, by which its trade and commerce would be much improved.

The trade of Enniscorthy would be much improved by making the river from thence to the town of Wexford navigable, which might be accomplished for a moderate sum. The interests of the towns of Mallow, Fermoy, Lismore, and Cappoquin; and the extensive districts on both sides of the river would be greatly advanced, by making the Blackwater navigable, which might be done at a small expense.

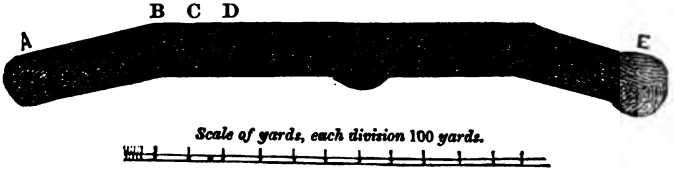
By the "standing orders" it is required "that the section for a turn-pike-road, cut, canal, reservoir, aqueduct, or railway, shall be drawn to the same horizontal scale as the plan, and to a vertical scale of not less than one inch to every 100 feet, and shall show the surface of the ground marked on the plan, and the intended level of the proposed work; and a datum horizontal line, which shall be the same throughout the whole length of the work, and shall have reference to some fixed point stated in writing on the section."

BREAKWATER.

Breakwater signifies a barrier, generally placed at the entrance of a harbour, to break off or diminish the force of the waves, as they advance towards the vessels moored within. The greatest work of this kind ever attempted in Britain, is that across the Bay of Plymouth. The exposed situation of the sound was long felt as an extreme inconvenience in the harbour, and it was at last determined to oppose the heavy swell which continually rolled in from the Atlantic, by building a breakwater at St. Carlos Rocks, about three miles south of Plymouth, in the middle of the sound, stretching across its entrance, occupying nearly half its width, and leaving a free passage for vessels at both its extremities. This great work, which was commenced in 1812, was planned by Mr. Rennie. It is not yet finished.

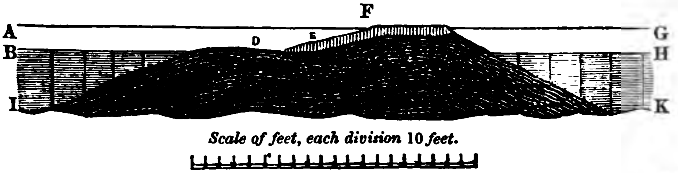
The accompanying figure is a plan of this stupendous and most useful work. AB, which represents the eastern arm of the breakwater, as it stood a short time ago, is 10 feet above low water, spring-tide. From B to C is finished with rubble; C to D is finished with masonry; D to E is finished with masonry.

Plan of Breakwater.



In this figure AG represents high water, spring-tides; BH low water, spring-tides; IK the original bottom, varying from 40 to 45 feet below low water mark; D the fore shore; E the slope at sea side; F the top, which is 45 feet wide. This breakwater is composed of stones raised in a neighbouring quarry, which were

Transverse section of finished part of Breakwater.



thrown in promiscuously, the largest however occupying the sea slope; some of these blocks weigh ten tons and upwards. The cavities are filled with rubble, lime screenings, and quarry rubbish, which were thrown into the promiscuous mass, serving to consolidate it. As the work advanced, a more solid description became necessary, to withstand the increased violence of the sea. Sir John Rennie, therefore, recommended that the surface should be cased with masonry, and a foreshore on the east side, increasing in substance and strength as it approached the west end. This end is composed of solid masonry, from low water to the top, doweled, joggled, dove-tailed, and cramped together.

Lest the air compressed by the waves should blow up the covering, Sir John recommended to leave vent-holes in the surface of the casing, through which the air might escape. The lower granite courses are laid horizontally upon their beds; so are the other bounding courses; all being substantially dove-tailed together, and also bolted to each other, and thus forming a barrier capable of resisting any shock to which, within probability, it might be liable. The mortar used for the masonry is composed of one part Italian pozzolana, one part aberthaw, or Plymouth lime, mixed up with two parts of fine sharp clean fresh water sand, all thoroughly mixed up together, using as little water as possible. The exterior beds and joints, for a few inches inwards, are pointed with the best roman cement.

By referring to the plan, it will be seen that the breakwater consists of three branches; the centre one being 1000 yards, and each of the extreme ones 350 yards; making the length at top, 1700 yards. At low water mark the length is 1770 yards. The exterior slope, taken below the line of low water, is about 3 or 4 feet horizontal to 1 foot perpendicular; but from low water upwards, which has been set artificially, the slope is 5 feet horizontal to 1 foot perpendicular. The slope next the land is about 2 feet horizontal to 1 foot perpendicular, from the base to the top. In addition to the sea slope, there is an exterior fore-shore, thirty feet wide at the extremity of the east end, fifty feet wide in the centre, and seventy feet wide at the extreme west end. The object of building this fore-shore is to break the waves before arriving at the main body of the work, by which their force is considerably diminished.

Near the centre of the inner slope is a jetty, at which boats may land under protection. At the western extremity is a circular head, 570 feet diameter, upon which a light-house is to be built, for the purpose of illuminating the entrance as well as the anchorage ground. The eastern entrance is half a mile wide, and varies from six to seven fathoms at low water; and the western entrance, which is of the same width, varies from seven to nine fathoms at low water, spring tides; and the anchorage varies from eight to nine fathoms at low water, spring tides.

For a more particular account of this arduous undertaking, consult a paper on the subject by Sir John Rennie, inserted in the Architect's and Civil Engineer's Journal.

DOCKS.

After what has been said on the subject of basins, little remains to be said on the construction of docks, the use of which is to keep the water at a constant level, for the accommodation of vessels. The most usual plan of constructing docks is to excavate a portion of the shore; sometimes, however, they are made by inclosing a part of the harbour with strong water-tight walls. The entrance to the docks may be by a simple sluice, closed by ordinary lock-gates, by which vessels can only enter them at high water: but when the entrance is supplied with a lock-gate, vessels may enter or pass out at any time of the tide. By making the gates convex towards the head-water, as may be seen at the custom-house docks in Dublin, they will bear a greater pressure.

In the construction of docks in situations where space is an object of consideration, the quantity of ground intended for such works should afford a maximum quantity of loading and discharging room. To lay out a given space, therefore, in such a manner as that a maximum number of ships may load and discharge at the same time, resolves itself into a mathematical problem of easy solution. The solution of the problem, however, varies with the form of the ground intended for the docks, and consequently no general construction can be given, applicable to every case. Besides affording the greatest quantity of quayage, sufficient space should be allowed for ships to pass in and out, as occasion may require. There should be also a sufficient quantity of warehouse or transit-shed room, and facilities for loading and unloading vessels.

Docks must be built in the most substantial manner, and must be sufficiently capacious for the probable trade of the place. The docks at Liverpool are good models for imitation.

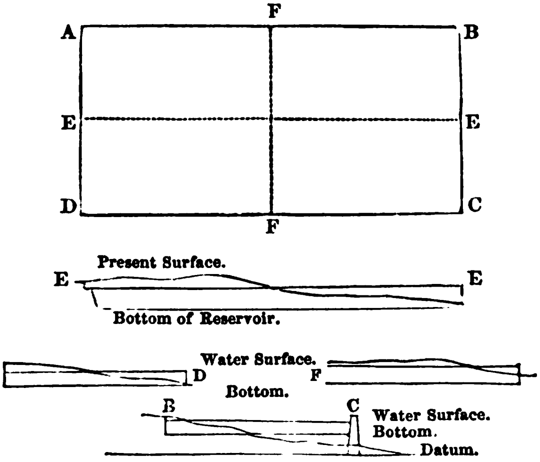
HARBOURS.

A harbour is a secure anchorage for ships, where they may ride with security during boisterous weather.

A harbour may be either natural or artificial. An artificial harbour is formed by enclosing a space on the coast between two arms, built sufficiently strong to resist the action of the sea, and thereby render the harbour more tranquil and secure for ships to anchor in. The approach should be easy and safe, and the mouth or entrance so situated as to prevent the swells from the sea acting with their full force on the shipping within. To effect this, one arm or jetty should be longer than the other; both arms should be curved, and terminated by circular heads, sufficiently large for the erection of a light-house or battery of cannon. These circular heads should not be nearer than 100 yards to each other, nor should the space between them exceed 500. Care should be taken also that the current shall not convey sand or mud into the harbour, which might soon fill it up, and render it too shallow.

The Kingstown harbour, now in progress of execution, under the skilful management of Mr. Barry Gibbon, C.E., promises to answer all the purposes for which it is intended; while that at Howth, built at an enormous expense, has answered no end whatever, except that a few fishing boats come into it occasionally. No public work of modern date has proved so complete a failure as this harbour, which proves that great professional names are not always a sufficient guarantee to the public, in securing advantages commensurate with expenses incurred.

By the "standing orders" it is required "that the plan may exhibit the height of the several embankments, and the depth of the several cuttings, respectively." By referring to the annexed figure it will appear that transverse sections right across the works must be taken at every material change of height occurring in the surface.



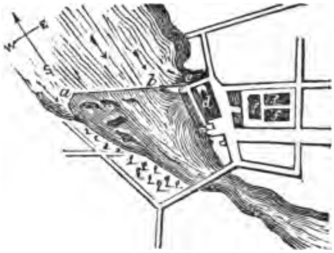
Cross Sections.
Scale 100 feet to 1 inch.

WATER-WORKS.

The most extensive water-works in North America are those of Philadelphia, called the Fairmount Waterworks, situate on the banks of the river Schuylkill, a short distance from the town. From the annual report of the watering committee, to the select and common councils of the city of Philadelphia, we learn that the sum expended in the execution of this great work was £276,206.

The water is raised by water-power into four large reservoirs, placed on a rocky eminence near the bank of the river Schuylkill, and after passing through gravel beds to be filtered, it is conveyed in two large mains to the outskirts of the town, and from thence into the various streets by smaller mains and branch-pipes.

The following is a ground-plan of the water-works, including a part of the river and the adjoining country. In order to obtain a fall of water for driving the water-wheels, a dam, represented by the letters *a b c*, was thrown across the river in an oblique direction. The mill-race is represented by *d*; the buildings containing the water-wheels and force-pumps by *e e*; and the filters and reservoirs for the reception of the water by *f f f*. The length of the dam, from bank to bank, is 1600 feet, and extends its influence in diminishing the velocity of the water, to a distance of six miles up the river. The rise of the tide is six feet, and the greatest depth of water in the line of the dam, at low water, spring tides, is 24 feet. From *b* to *a*, the bottom of the river is entirely composed of bare rock, part of which, at the western side of the river, is exposed during low water; and from *c* to *b* consists of rock covered with mud, about 11 feet in depth.



The direction of the dam forms an angle of 45 degrees with that of the stream, by which the strength of the structure is considerably increased; the mass of the dam "opposed to any given section of the stream is greater directly as the cosine, or inversely as the sine of the angle formed by the line of the dam, and the direction of the stream impinging on it."

The part extending from *c* to *b* was first formed, and consists of a large mound of rubble stones and earth thrown into the river. Its base measures 270 feet in length, 150 feet in breadth, and 12 feet at top, its upper slope or face being cased with large stones, which preserve its exposed face from the wash of the river. The point *b*, which denotes the termination of the dam, is protected by a cut-stone pier, measuring 28 feet by 20 feet, and is built in water 28 feet in depth. The overfall dam extends from *b* to *a*, and measures 1204 feet in length, and is founded on a rocky bottom, on which it was found impossible to construct a mound of rubble to form this part of the dam, according to the plan followed in the first part of the structure, which was founded on a bottom composed of mud. Therefore, to retain the stones on the shelving rock required some ingenuity of contrivance.

The overfall dam consists of a very strong wooden crib, "which was formed in separate compartments, and sunk in small portions in the line of the dam, by filling it with stones." The cribs, which are prevented from floating by being hearted with rubble stones, are formed of logs of wood, measuring 20 by 18 inches, connected together by strong dove-tailing, notched three inches deep.

"The size of the wooden frame, measured in the direction of the stream, is 72 feet; and the separate compartments of which it was formed measured 27 feet in breadth.

"The part of the dam over which the water flows, marked *a d*, and also the posterior part of it, *a b*, are covered with planking six inches in thickness."

The cribs being placed one after another over the spot which they were destined to occupy, they were filled with stones, which made them sink gradually till they reached the bottom of the river. All the cribs being sunk, the portions of them which stood above the low-water mark were firmly connected together, forming one frame-work, which was secured in its place by rubble-stone hearting and earth, which also kept it from leaking. The erection of the dam having impeded the navigation of the river, the water company were obliged to compensate the Schuylkill navigation company by forming the canal marked *h h*, for the passage of their coal barges.

The water enters the mill-race *d*, by three arches at *c*, which have a water-way sixty-eight feet in breadth, admitting, in its ordinary state, a body of water six feet in depth.

By opening a sluice communicating with the part of the river below the dam, the whole of the water can be drawn off from the mill-race. The arch-ways can be shut by means of gates.

From *d*, the water flows through the wheel-houses *e e*, and drives the water-wheels, escaping into the Schuylkill. The wheel-houses contain eight wheels and eight force-pumps, which are employed to raise the water. Each pump raises 530,000 gallons per day; and the whole quantity distributed from the reservoirs, in the same time, is 3,122,664 gallons.

The water-wheels vary from 15 to 16 feet in diameter; they are 15 feet in breadth, and make thirteen revolutions in one minute. The buckets, spokes, and rims are formed of wood, the wheels revolving on axles weighing five tons each. When the back-water rises 16 inches in the wheels, their working is retarded. They are generally stopped about 64 hours every month, on account of the rising of the back-water. The pumps are common double-acting force-pumps, having a stroke of six feet, worked by cranks attached to the axles of the paddle-wheels. The water is forced 92 feet high. The cast-iron main, leading from each force-pump to the reservoirs, is 16 inches in diameter. The communication between the force-pumps and the reservoirs can be cut off by means of a stop-cock, which has the effect of relieving the pumps from so great a pressure as is imposed by this column of water when the pumps are not at work.

There are four reservoirs, whose aggregate area is six acres, placed on an elevation of 102 feet above the level of low water, and 56 feet above the highest part of the streets of Philadelphia. The water is retained in the reservoirs by means of artificial walls and embankments. The side walls of the reservoirs are built with stone, behind which there is a backing of clay-puddle, two feet thick, the whole being surrounded by an embankment of earth, sloping at the rate of 1 to 1, and covered with sods. The reservoirs are paved with bricks, laid with lime-mortar on a layer of clay-puddle, and well grouted, to prevent leakage. The reservoirs contain 22,000,000 gallons of water, which stands in them to the depth of 12 feet 3 inches. The water, after being discharged from the force-pumps into one of the reservoirs, passes through all the other reservoirs, between each of which there is a filter, which deprives the water, in its passage, of all the impurities it contains.

The cast-iron pipes, through which the water is conveyed through the streets, measure 98¾ miles. The two mains, leading from the reservoirs to the town, are 22 inches in diameter, while those laid in the streets are only from 3 to 12 inches. The pipes are connected together by spigot and faucet joints. The average cost of the mains and pipes was *7s.* 1½*d.* per lineal foot.

Wherever water-power can be substituted for that of steam, a great saving will be effected.

The town of Richmond, in Virginia, is supplied with water from the James river, in the same manner as at Philadelphia. In these works two wheels are employed, which raise the water 160 feet into two reservoirs, measuring 194 feet in length, 104 feet in breadth, and 10 feet 8 inches in depth, and which therefore are capable of containing upwards of two millions of gallons of water. The water is made to pass through two gravel filters, which purify it. The water falls on the wheels from the height of ten feet, the diameter of each being eighteen feet, and breadth ten feet. The barrels of the two force-pumps are nine inches in diameter, the length of stroke being six feet. When only one wheel is at work, 400,000 gallons of water are raised in 24 hours.

The cast-iron main, leading from the pumps to the reservoir, is eight inches in diameter. The works cost about £20,000.

The city of Limerick was for a long time very badly supplied with water; the quantity being scanty, and the quality of the very worst description. The condition of the city, however, is now somewhat improved in this respect. In or about the year 1834, a company was formed, called the "Limerick Pipe-water Company," and incorporated by act of parliament, for the purpose of supplying the city with water. Pipes are laid down through the entire city, but the inhabitants, in numerous instances, do not take advantage of the supply, being under the impression that the company's charges are too high, and the quality not of the best. The tank which supplies the city is about a quarter of a mile from it, and commands a sufficient height for the water to flow into all the houses. The supply is procured from the river Shannon, at Plassy, about a mile from the city, and forced thence to the tank, a distance of about a mile, up an inclined plane, the force employed being two steam-engines of twenty horse power each.

It would have been better to have brought the water from the Ballysimon wells, distant two or three miles from the city, which would afford a sufficient supply of the purest water.

The city of Cork is supplied with water from the river Lee. The water is raised from the river into a reservoir near Sunday's Well, which commands the city; the pumps employed being worked by two large wheels, which are turned by the stream.

The town of Belfast has long felt the want of a sufficient supply of water; depending, in a great measure, on the uncertain and scanty supply afforded by the water carts.

This town might be abundantly supplied from the streams descending from the neighbouring heights. It is probable there may be some legal difficulty in applying these streams to the use of the town. If some vested right did not prevent their application to so useful a purpose, it is to be supposed that the spirited inhabitants of that rising town would not have suffered a want of such magnitude to exist, without having long ere this supplied it.

The City of Dublin is supplied with water from the Grand and Royal Canals, the former supplying that part of the city lying south of the River Liffey, and the latter that on the north side. In the immediate neighbourhood of the city are two basins, fed from the canals, the one on the north, and the other on the south side. In these basins the water is filtered, and from them conducted through metal pipes to the different streets, for the use of the inhabitants. The quality is good, and the quantity sufficient for culinary and other domestic purposes; but in cases of accidents by fire, the supply is lamentably deficient. The want of an ample quantity of water, and a systematic or properly organised plan to arrest the progress of the destructive element, are in most instances the cause of the loss of much valuable life and property, which a more abundant supply, under better management, might have prevented.

To compute the quantity of water that passes through a bridge or any section of a river.—Procure a slender wooden rod, to one end of which attach a weight sufficient to sink it, leaving the other end above the water. This being put into the stream whose velocity is required, the greater velocity at the surface will make it incline towards the direction in which the water runs, and therefore, when it has acquired an equilibrium, it must move in an oblique position, the velocity being pretty nearly equal to that of the water at that place. As the velocity of the stream varies with its depth, the experiment should be tried in different parts of the cross-section, and a mean of all taken for the mean velocity. Now, having ascertained the mean velocity of the stream, the next thing to be done is to find the area of the cross-section, by taking the depths at several places, at equal distances across the stream. In making these experiments, a stop-watch, which tells the time to seconds, is necessary. M. Pitot invented a Potamometer, or stream measurer, which is by far the best for ascertaining the velocity of water. It consists of a tube of glass bent at right angles, the shorter branch being funnel shaped at the mouth, and the longer branch raised vertically to exhibit the elevation of the water in the tube, which corresponds to its velocity. The scale on the vertical branch is graduated by the following rule:

To find the height due to a given velocity, square the velocity per second, and divide by 64; the quotient will give the required height in feet. "On this principle, the divisions on the scale of the potamometer for miles, would be numbered at the following heights above the surface, in inches:

Divisions	1	2	3	4	5	6	7	8	9
Heights	.4	1.6	3.6	6.4	10	14.5	19.7	25.8	32.7

Doctor Gregory says that "a similar instrument, made partly of tin, and cemented to a tube of glass, might be introduced into a ship or steam-boat, for measuring the ship's way at sea, or for ascertaining the velocity of the steam-boat. If introduced into the cabin, the passengers could tell, by consulting the scale, the rate per hour at which the vessel was sailing, and consequently how soon they were likely to reach port."

To illustrate this, let us suppose the breadth of the river to be 60 feet, and the depths at six different equidistant places, to be 2, 4, 5, 7, 5, 3 feet, the first and last being the depths at the banks. Here $2+3=5$, and $5\div2=2\frac{1}{2}$; then $(2\frac{1}{2}+4+5+7+5)\div5=23\frac{1}{2}\div5=4\frac{7}{10}$, and $4\frac{7}{10}\times60=282$ square feet for the area of the cross-section. If we now suppose the velocities taken at six different places, in the cross-section, to be 50, 56, 60, 70, 60, 54 feet per minute, the mean velocity will be $(50+56+60+70+60+54)\div6=350\div6=58\frac{1}{3}$ feet, for the mean velocity per minute: then $282\times58\frac{1}{3}=16450$ cubic feet, the quantity that flows through the section of a river in one minute.

To find the force of water impinging directly against a plane surface.—Multiply the area of the surface in feet, by the square of the velocity in feet per second, and the product, diminished by $\frac{1}{40}$th part, will be the force required in lbs. nearly. If we suppose the velocities in feet, per second, to be 1, 2, 3, 4, 5, 6, 7, 8, 9; the forces in lbs. upon one square foot of surface, will be 1, 4, 9, $15\frac{1}{2}$, $24\frac{3}{8}$, 35, $48\frac{3}{4}$, $62\frac{1}{2}$, and 79lbs. respectively.

When the velocity is given in miles per hour; you multiply the area of the surface in feet, by the square of the velocity, and double the product increased by $\frac{1}{20}$th part, for the force required in lbs. nearly. If we suppose the velocities per hour, in miles, to be 1, 2, 3, 4, 5, 6, 7, 8, 9, the force in lbs. on a square foot would be 2.1, 8.4, 18.9, 33.6, 52.5, 75.6, 102.9, 134.4, 170.1 respectively.

To find the effective power of a stream, as available for driving machinery.—Multiply the force due to the velocity by the transverse section of the stream, and this product again by the velocity per minute, and divide this last product by the estimate of a horse's power, the quotient will give the effective power required. As an example, let us suppose a mill-race to be 4 feet broad, 3 feet deep, and running at the rate of 5 miles an hour; the effective power would be 51½ horses' power, nearly.

For the force on a square foot due to the velocity is 52.5, and the area of the cross-section of the stream is $4 \times 3 = 12$ feet; therefore the whole force of the stream is $12 \times 52.5 = 630$ lbs; which, multiplied by the velocity, 440 feet per minute, gives 277200 lbs per minute for the effective power. Now, a horse's power at the velocity of 5 miles an hour, or 440 feet per minute, is 21560 lbs per minute. But a horse could not continue at work more than six hours a day, whereas the action of the stream continues for 24 hours; therefore the horse's power must be taken at $21560 \div 4 = 5390$ lbs. Hence, $277200 \div 5390 = 51\frac{1}{2}$ horse's power, nearly. For the latter part of this operation, see the article on horse power.

To find the effective power of a stream or waterfall.—Multiply the effective discharge in cubic feet per minute, by the height of the fall, and this product again by 62½; divide by 44000, and the quotient will give the horse power equivalent to the stream.

As an example, let us suppose the effective discharge of a stream, with a fall of 20 feet, to be 1400 cubic feet of water per minute, the number of horse power is required.

$1400 \times 20 \times 62\frac{1}{2} = 1750000$; then $1750000 \div 44000 = 39\frac{4}{5}$ nearly. Any one wishing more information on this and other subjects connected with water power, mill work, steam power, &c. may consult the works of Tredgold, Galloway, Gregory, Buchanan, Leslie, Lardner, and Wallace. Wallace's little work, entitled "Practical Mechanic's Pocket Guide," is very useful, as it contains a vast number of practical rules, judiciously chosen and well arranged.

HORSE POWER.

When horse power is employed upon a railway, it is evident that some certain speed and load are best suited to the animal. It is therefore of importance to know how to load and drive the animal, so as to produce the greatest effect without injury to himself. This enquiry necessarily involves the duration of labour, which experience proves ought to be 6 hours each day, walking at the rate of 3 miles per hour, and loaded with 125 ℔. To arrive at this conclusion, much must have been derived from observation. The power of a horse has been variously rated. Boulton and Watt are of opinion that a horse is able to raise 32,000 ℔, avoirdupoise, 1 foot high in 1 minute; others make it 27,500, 33,000, and 44,000 ℔.

It is common, in calculating the power of engines, to allow for the horse's power 44,000 ℔, or 33,000 ℔, at 1 foot per minute. It should, however, be stated which of the two is employed in the calculation.

To calculate the velocity corresponding to different durations of labour.—Put f for the muscular force, which may be continued day after day without injury to the animal, w for the weight of the horse, and s for the space described in a given time; then the velocity $v = \sqrt{\frac{64 f s}{w}}$. Now it is evident that the space described is inversely as the duration of the day's labour; that is, s varies as $\frac{1}{h}$, h being the hours that the horse works in a day; then substituting for s we get $v = \sqrt{\frac{64 f}{w h}}$. Now if we make the muscular force of the horse to his weight as 3.374 to 1, or as 3.4 to 1, and substitute this for $\frac{f}{w}$, we get $v = \frac{14.7}{\sqrt{h}}$. If we substitute 1, 2, 3, 4, 5, 6, 7, 8 for h, respectively, we get the corresponding maximum velocity per hour in miles.

1h.	2hrs.	3hrs.	4hrs.	5hrs.	6hrs.	7hrs.	8hrs.
14.7m.	10.4m.	8.5m.	7.3m.	6.6m.	6m.	5.5m.	5.2m.

Mr. Tredgold, and others, consider the law of decrease of speed by increased duration of labour, when a horse moves on a level road unloaded, to be that exhibtied in the above tablet. When the horse moves up hill, the velocity will decrease in proportion to the sine of the angle of inclination; and when he descends a hill, the velocity will increase in the same proportion.

Maximum of useful effect.—Adopting the notation in Gregory's Mechanics, we put $P =$ the absolute effort of any moving force, when it has no velocity; and suppose it not capable of any effort when the velocity is W, let F be the effort answering the velocity V. Then the force being uniform, $F = P\,(1 - \frac{V}{W})^2$. The difference between the velocities W and V is efficient, and the action being constant, varies as the square of the efficient velocity; therefore $P : F :: (W-P)^2 : (W-V)^2$. Hence we have $F = P\left(\frac{W-V}{W}\right)^2 = P\left(1-\frac{V}{W}\right)^2$.

This formula is applicable to the action of animals as well as of machines, the action of the former being supposed to be constant, which may be taken as such; as though the pressure of the animal may not be strictly uniform for any considerable time, yet by careful management, it might be made very nearly so.

Retaining the same notation, we get $W = \frac{V\sqrt{P}}{\sqrt{P}-\sqrt{F}}$.

This is an expression which applies directly to the velocity of animals when loaded, as compared with their greatest velocities when unloaded; the greatest velocity of an animal, when unloaded, is to his velocity when impeded by a given resistance, as the square root of its absolute force, to the difference of the square roots of its absolute and efficient forces.

It appears from articles 363 and 365, in Gregory's Mechanics, that when a machine is put into motion, the velocities of the impelled and working points are inversely as the forces which are in equilibrio, when applied to those points in the direction of their motion. Therefore, putting f to denote the resistance, when reduced to the working point, and v its velocity; while F and V denote the force acting at the impelled point, and its velocity; then we shall have $FV = fv$, and $FVt = fvt$, by introducing the time t. From which it appears, that in all working machines which have acquired a uniform motion, the performance of the machine is equal to the momentum of impulse.

Put F for the effort of force upon the impelled point of a machine, moving with the velocity V, the velocity being W, when $F = O$, and putting the relative velocity $W - V = w$; then from the equation above we have $F = P(\frac{W-V}{W})^2$; therefore the momentum of impulse will be $VP(\frac{w}{W})^2 = P\frac{w^2}{W^2}(W-w)$: for $V = W - w$. Now making the value of FV a maximum, and suppressing the constant quantities, we shall have the differential of $w^3(W-w) = O$; that is, when w is variable, and the expression a maximum, the differential of $w^2W - w^3 = O$; that is, $2wdw.W - 3w^3dw = o$, or $2wdw.W = 3.w^2dw$, and hence $2W = 3w$, or $W = \frac{2}{3}W$. Hence $V = W - w = W - \frac{2}{3}W = \frac{1}{3}W$.

When by the construction of the machine, we have the ratio of V to v given, and the resistance is susceptible of variation, we must load the machine more or less, till the velocity of the impelled point is one-third of the greatest velocity of the force, then will the work be a maximum. Also, the work done by an animal is a maximum, when the greatest velocity with which it moves, when unimpeded, is three times his velocity when loaded.

Now, we have $F = P\frac{w^2}{W^2}$, and substituting $\frac{2}{3}W$ for w, we get $F = P(\frac{\frac{4}{9}W^2}{W^2}) = \frac{4}{9}P$, and in the case of a maximum $FV = \frac{4}{8}PV = \frac{4}{9}P.\frac{1}{3}W = \frac{4}{27}PW$, for the momentum of impulse, or for the work done, when the machine is in its best state. Therefore when the resistance is a given quantity, we must make $V : v :: 9f : 4P$; and this structure of the machine will give the maximum effect $= \frac{4}{27}PW$. This is applicable to the action of men and horses.

The investigation is considerably simplified, in case of animal power, by considering every exertion of animal strength as represented by that which is necessary to carry a weight.

Whatever way the animal employs his strength, it is obvious that a certain load carried with a certain speed may always be considered as an equivalent exertion. In considering this subject, two things are perfectly obvious; namely, that as the load is increased, every thing else remaining the same, the speed of the animal must be diminished; and that there are two extreme cases producing no useful effect whatever. When the animal moves with its utmost speed, it is clear he can carry no load, and when the load is so much increased as that the animal can barely sustain it, without being able to move it, the useful effect in this case, as well as in the last is nothing.

Did we know the law by which the load increases with a given diminution of speed, or the contrary, it would then be a task of no great difficulty to ascertain the precise speed and load of the animal producing the most useful effect. There are two elements, therefore, entering into the solution of the problem for finding the most useful effect—" the load which is borne, and the speed or velocity with which it is carried. The useful effect is, in fact, estimated by multiplying the load by the speed. This will be easily understood by an example. Suppose one horse carry two hundred weight six miles an hour, and another carry three hundred weight four miles an hour. The load of the former is two, and the speed six; the product or useful effect being twelve. The load of the latter is three, and the speed four; the useful effect being twelve. The propriety of considering the useful effect to be equal in these two cases, will appear very evident, if we consider both horses to be employed in transporting weights between two places, distant one mile asunder, for six hours. The first horse will carry, in the six hours, 72 hundred weight between the two places; for he will make thirty six turns, travelling for six hours at six miles an hour, and at each turn he will carry two hundred weight. The other horse will make but twenty-four turns, since he travels only four miles an hour; but then, in each turn, he will carry three hundred weight; and, therefore, he will also transport in the given time 72 hundred weight between the two places." This reasoning is convincing, and shews the propriety of estimating the useful effect by the product of the numbers which express the load and the speed with which it is carried.

Before we enter upon the calculation for finding the most useful effect, it is necessary to state, that from all the experiments which have been tried, the load increases in the same ratio as the square of the difference between the greatest velocity with which the animal can move, when unloaded, and the velocity with which it can move the load. Hence, if we put $X =$ greatest speed when unloaded, and $x =$ DO — when loaded; $L =$ greatest load the horse can sustain, without being able to move it, and $l =$ any load less than L. Then from the principles laid down, $l \times x =$ useful effect, and l increases as $(X-x)^2$, and the maximum useful effect is properly represented by $(X-x)^2 \times x = w$. By differentiating this, we get
$\frac{dw}{dx} = (X-x)^2 - 2\,(X-x).\,x$, which being a maximum is $= 0$; that is, $X^2 - 4Xx + 3x^2 = (X-x) \times (X-3x) = 0$. The two roots of this equation are $x = X$, and $x = \frac{1}{3}X$. When $x = X$, the useful effect is nothing; but when $x = \frac{1}{3}X$, we have $l = (X - \frac{1}{3}X)^2 = \frac{4}{9}X^2$.

Hence, the load corresponding to one-third of the greatest speed is $\frac{4}{9}$ of the greatest load, because $L=X^2$. By taking the second differential, we get $\frac{d^2w}{dx^2}=-3(X-x)-(X-3x)=-4X+6x$, in which, if we substitute $\frac{1}{3}X$ for x, we shall find $-4X+2X=-2X$. As this is a negative value, it is evident that $\frac{1}{3}X$ corresponds to a maximum value of w, the useful effect. This will appear plainer by reducing it to an arithmetical table.

As in one of the excellent numbers published by the society for the diffusion of useful knowledge, let us suppose that the number 15 represents the greatest speed, when unloaded, and that the square of 15, or 225, represents the greatest load which the animal can sustain without being able to move it. "The signification of the units which compose the number 15, will be found, by dividing the space through which the animal would move in a given time, suppose one hour, into 15 equal parts: each of these parts will be expressed by an unit of the number 15, which expresses the greatest unloaded speed; and the signification of the units of 225 will be found, by dividing the greatest load which can be sustained without moving, into 225 equal parts; one of these parts will be expressed by an unit of the number 225, which expresses the greatest load. The following table gives for each degree of speed from 1 to 15, the corresponding load and useful effect:

Speed	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Load	225	196	169	144	121	100	81	64	49	36	25	16	9	4	1	0
Useful effect	0	196	338	432	484	500	486	448	392	324	250	176	108	52	14	0

From an inspection of this table it will be seen that the useful effect is 500, the product of 5, which is one-third of the greatest speed, by 100, which is the four-ninths of the greatest load which the animal is able to sustain without moving—a result which will always be found, whatever number we take to represent the greatest speed. This table also shews that a much greater useful effect is attained by the slower motions with heavier loads, than by quicker motions with lighter loads.

To determine the power of a double acting engine.—Let the force of the steam in the boiler be denoted by 1.000. Then, according to Tredgold, besides the loss from uncondensed steam, there is a loss,

1. By the force producing the motion of the steam into the cylinder	.007
2. By the cooling in the cylinder and pipes ...	.016
3. By the friction of the piston, and loss ...	.125
4. By the force necessary to expel the steam through the pipes	.007
5. By the force required to open and close the valves, raise injection water, and the friction of the axis ...	.063
6. By the steam being cut off before the end of the stroke	.100
7. By the power required to work the air pump ...	.050
	.366
	662

Now, the force of the steam being generally 35 inches of mercury in the boiler, the temperature of the uncondensed steam 120°, and its force 3.7 inches; hence, $35 \times .632 - 3.7 = 18.42$ inches, or 7.1lbs per circular inch, for the mean effective pressure on the piston.

Rule.—Multiply the mean effective pressure on the piston by the square of its diameter in inches, and that product by the velocity in feet per minute, the result will be the effective power in ℔s, raised 1 foot high per minute. Then to find the horse power, divide the result by 33000.

Example.—The diameter of the cylinder of a double engine being 24 inches, the length of the stroke 5 feet, the number of strokes per minute $21\frac{1}{2}$, and the force of the steam in the boiler 35 inches of mercury, or 5 inches above the pressure of the atmosphere; the power is required.

The velocity is $2 \times 5 \times 21\frac{1}{2} = 215$ feet per minute; therefore, $7.1 \times 24^2 \times 215 = 879264$ ℔s raised 1 foot high per minute, or $879264 \div 33000 = 26.64$ horse power.

To find the mean pressure on the piston of an expansive engine, the part of the stroke at which the steam is cut off being $\frac{1}{n}$, divide 2.3 times the common log. of n by n, and multiply the quotient by the whole force of the steam in the boiler, in ℔s per circular inch; the result will be the mean moving force on the piston, per circular inch.

Example.—Suppose the steam to be cut off at $\frac{1}{2.1}$ of the stroke; then $n = 2.1$, and the log. of 2.1 is 3.2222, then, $2.3 \times .32222 \div 2.1 = .354$, and as the pressure corresponding to this point of cutting off the steam is 35 inches, or 13.5 ℔s per circular inch, we have $13.5 \times .354 = 4.8$ ℔s per circular inch, the mean pressure.

Taking the dimensions and force of steam of the engine in the last example, its power as an expansive engine would be $4.8 \times 24^2 \times 215 = 594432$ ℔s raised 1 foot high per minute, or $594432 \div 33000 = 18$ horse power.

These two examples have been taken from Tredgold's treatise on the steam engine; a work very deservedly in high estimation.

The following method is that practised by American engineers, to find the power of their engines. If we suppose the diameter of the piston to be 43 inches, the pressure of the steam in the boiler 45℔s on the square inch, the length of the stroke 10 feet, making 27 double strokes in a minute, the engine working expansively, and the steam cut off at half stroke; required the power.

First, $43^2 \times .7854 = 1452.2$, area of piston; and as the steam is cut off at half stroke, $45 \div 2 = 22.5$ ℔s is assumed as the pressure on the square inch of the piston, to which 10 ℔s are added as the pressure of the atmosphere, obtained by the use of the condenser, making the whole effective pressure on every square inch of the piston 32.5 ℔s. Now, $27 \times 2 \times 10 = 540$ feet, space passed through by the piston in one minute. Hence, $1452.2 \times 32.5 \times 540 \div 33000 = 772.3$, horse power. One-third of this power is supposed to be expended in working the pumps and overcoming the friction of the machinery, and a power of 514.8 horses remains as the true force exerted in propelling a vessel, or driving any other description of machinery.

DRAINING OF LAKES.

There are generally three objects to be attained by the drainage of lakes. In the first place, when the water is removed, the land exposed is gained. In the second place, when the surface of a lake is lowered, or the water altogether removed, a fall is very generally obtained for the drainage of the adjoining marshes and low lands. And in the third place, the marl and other deposits in the bottom serve as excellent manure.

Before commencing the drainage of a lake, many circumstances are to be considered. The depth of the lake, the dimensions of the cut necessary to carry off the water, the nature of the soil through which the cut runs, and its length, must all be ascertained, by sounding, boring, and levelling.

It is a matter of importance to ascertain the sources from which the lake is supplied, and the increased altitude of the surface in a given time, during heavy floods; also the amount of fall at command. Without these elements, no one can determine the dimensions of the cut sufficient to carry off the water in times of flood, so that none may accumulate. When the dimensions of such a cut is merely a matter of guess-work, it is a thousand to one if it be not either too large or too small for the required duty. When it is too small, an accumulation of water is the consequence: and when too large, an unnecessary expense has been incurred, which might have been saved by calculations founded upon proper data. When the length, cross-section, and nature of the ground to be cut through are ascertained, then an estimate of the expenses can be formed, which being compared with the probable return, will shew the gain or loss resulting from the undertaking.

It very often happens that the drainage of a lake can be accomplished more effectually by making a side or new cut, than through the natural outlet. Many circumstances are to be considered in determining the direction of the cut: the fall which can be obtained, the nature of the subsoil or rock, the length of the cut, and the direction of the lake stream, are all to be compared, and that possessing most advantages chosen. Straightness of direction is also to be taken into the account, being preferable to a crooked one. We could not perhaps give better instructions in this department of draining, than may be gathered from our report on the drainage of Lough Neagh, one of the largest lakes in Europe; we therefore copy it verbatum.

"In conformity with instructions received from the Lough Neagh Improvement Company, I have caused surveys to be made of, and examined myself personally, all the shores of Lough Neagh, and the banks of such of its tributary rivers and streams as are subject to inundation. I have also examined the several causes that conspire to raise the waters above the summer level,* and also caused plans and sections to be prepared, and levels taken, with a view to prevent the water from rising above that level, and thereby obviate the incalculable injury done to a vast extent of country by the autumnal and winter floods, which, for a period of several months, cover thousands of acres of the richest soil, to a depth of from four to seven feet. This Lough contains 91272 acres, and receives the waters of seven considerable rivers, and innumerable streams, and has but one natural outlet for the discharge of all these waters: namely, the lower Bann. This river, as it issues from the Lough, winds its course in a zig-zag direction for some miles over a horizontal surface, and is crossed by a bar at Toom, within a few yards of the lake, over which there is but fifteen inches depth of water in summer. When the rainy season commences in that part of the country, those rivers contribute more water to the lough than its present outlet is capable to discharge in a given time. Its surface therefore continues to rise, while the influx exceeds the efflux, and in time, surmounting the surrounding barriers, the redundant waters immediately diffuse themselves over the shores, which continue submerged for a great part of the year, by which the soil is rendered altogether useless for agricultural purposes, and incapable of producing any thing but useless water weeds, and reedy grass, 'totally unfit for horses, and very indifferent for any kind of cattle.' As the surface of the lough rises, the waters of the several rivers and streams, which lie low, are obstructed in their passage into it, and being forced back by the increased elevation of the lake, they soon become swollen, flooding their banks, in some places, many miles, which remain in this state till the surface of the lake is again lowered by the slow discharge through the channel of the Lower Bann.

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* The plan here contemplated, is to keep the water at summer level, and not to drain it completely.

"The waters issuing from Lough Neagh pass through Lough Beg, distant from the former about one English mile, and containing about 2,551 English acres. At the lower extremity of Lough Beg, the waters force their way through the Lower Bann, till obstructed in their course at Portglenone by a bar of rubble stone, and at Portna by one of those formidable barriers so common in the north of Ireland, called whin-dykes, which crosses the river at that place. Another ledge of rocks, similar to that at Portna, obstructs the passage of the waters at Moyvannagher, and a third at the Salmon Leap, a short distance from Coleraine. There are other obstacles, composed of sand, gravel, and loose stones, which I shall notice hereafter.

"The Lower Bann, being a series of horizontal reaches, intersected by these natural barriers, must necessarily overflow such portions of land as lie below their level. The consequences resulting to the inhabitants from those floods cannot be better described than by taking a few passages from an excellent pamphlet on this subject, by John Obins Woodhouse, Esq. of Portadown:—

'Useless water weeds and rushes prevail to a great extent, and even this poor produce can with uncertainty be saved; and it is calculated that the occupiers lose one crop out of three by the early rising of the floods. Besides these disadvantages, no kind of agriculture can be attempted, and the plough is unknown in these lands; and no person would dare to erect a habitation within reach of the annual inundation. Year after year they remain almost a desert, giving no employment to the labourer, of very little value to the owner, and extremely prejudicial to the health of the inhabitants of the neighbourhood. It is, indeed, a melancholy sight to see, in winter time, such vast floods covering lands in all directions, which might, at the same time, be otherwise most usefully employed. Looking either from Toom Bridge, or the bridge at Portadown, in every direction the eye can turn, you see nothing but one sheet of water, covering lands composed of the finest alluvial soil, and oftentimes studded with hay-[illegible]ks, either floating down the stream, or rotting within

[illegible]

sight of the owners, [illegible] destruction."

"On [illegible] I was struck [illegible] or spirited [illegible] of this vast tract [illegible] densely inhabited [illegible] industry and [illegible] of land and [illegible] year, to [illegible]

"The present [illegible] round Lough [illegible] waters, is one of great [illegible] sought is very easily [illegible] existing [illegible] speedy and [illegible] owners and [illegible] and thousands of [illegible] poor-house, [illegible] of the property of [illegible] and a real [illegible] rack-rents and [illegible] which they are but badly able to pay.

"Before entering upon my plan of drainage, it may be necessary for me to shew, from the levels taken, that a sufficient fall can be commanded to effect the object proposed. Commencing at the lakes and proceeding down the river, the first fall that occurs is at Portna. The height of this fall is seventeen feet, in a distance of about eight hundred yards. At Moyvannaher, three miles distant from Portna, a fall of twelve feet and a half is obtained, and a short dis tance below it, at a place called the Vow, there are two falls, amounting together to three feet. Another fall of twenty inches is produced at the Laughans, six miles distant from the Vow; and one mile and a half below the Laughans, the ridge of rocks at the Salmon Leap produces the last fall of thirteen feet, giving in the whole distance a fall of forty-seven feet.

"Having thus far shewn the several causes that conspire to inundate the neighbouring districts of the lake, and also that sufficient falls present themselves on the Lower Bann for their drainage; the next duty I have to discharge is to describe the mode which appears to me to be the most effectual, and at the same time the most economical to effect the object. The first thing I would recommend is, to cut a new channel through the Crea Bog, commencing two hundred and forty-nine perches from the junction of the two roads leading from Toom Bridge, and directing its course a little to the left of the north-west extremity of the Crea Island. The length of this proposed cut is one mile; breadth at top, three hundred feet; and at bottom, two hundred and fifty feet; and must be cut to a depth of sev below the summer surface of the lake. T dimensions have been calculated upon scientific p ciples, the required data having been furnished by person who kept a daily registry of the different increased heights of the surface water of the lake in times of flood. The bar at Portna may be removed by dredging, so may that near the New Ferry. The bar of rocks at Portna must be cut down to a graduated depth, as exhibited in my section of the river. This is the principal obstacle that keeps the water above it at ts present level; the removal of this bar, therefore, assisted by a fall of seventeen feet, will give the stream passing through the cut such a velocity as will keep the channel free from future accumulation of bars or shoals. The cuts to be made at Moyvannaher and the Salmon Leap diminish in capacity inversely as the velocity of the stream increases at these places, as may be seen in my section.

"The bar at the Laughans may be deepened by dredging the channel at the west side of the island, situate in the middle of the river, at that place. The new channel, which I propose to cut through the Crea Bog, possesses many advantages that cannot possibly be obtained at any other point of the lake. In the first place, it is the shortest distance between Lough Neagh, from which the waters issue, and Lough Beg, through which they must pass. In the second place, the ground through which it passes is very easily excavated, being composed of a surface stratum of sand, two feet deep, resting upon a substratum of tenacious clay, free from gravel, stones, or rocks. In the third place, the stream through the natural channel of Lough Neagh, is conducted nearly in a straight line till it enters that part of the Bann issuing out of Lough Beg, by which its free circulation is promoted, unimpeded by any abrupt turns or angles, which should always be avoided in such cases.

"The Upper Bann and Blackwater rivers gliding along the lake, form one common channel, not far distant from the shores of the county of Tyrone. This channel directs the course of all the rivers and streams from the western side of the lake, as far as Toom. The rivers and streams from the eastern side of the lake, uniting in one common receptacle, are prevented from proceeding northward by the land at Shane's Castle, which crossing their direction at right angles, constrains them to flow in a north-westerly direction, ultimately forming one common channel with the former, which directs its course to the new passage which I propose to cut through the Crea. Though the velocity of the lake stream is at present almost imperceptible, yet, when a passage is effected in a proper direction, its rapidity will soon become apparent. The present outlet at Toom Bridge would not, by any alteration, well effect the object proposed; it is too far south from the natural lake channel, and is bent in its course at Captain O'Neale's Castle, a little below the bridge, which would always have the effect of retarding the progress of the stream; and the same causes that have produced the bar near the bridge, would still continue to operate. Any other point farther south than the bridge, would be still more unfavourable for the cut. I would not recommend these works to be carried on simultaneously; they should be done by degrees, in the high summer months.

"The bar at Portna should be first removed; after which the river at Portglenone and Newferry should be deepened, which should, as before stated, be effected by dredging. The river at Portglenone has a bridge over it, which should be replaced by a new one, the present being an old and infirm structure. The new channel through the Crea might next be made; this new channel, crossing two public roads from Toom, would require two bridges, which I would recommend should be built with wood; such structures offering less resistance to the passage of water than stone bridges.

The keeping of the lake at summer level will not affect the navigation of the Upper Bann or Blackwater rivers. The bars at their entrances into the lake should be dredged out, or locks and other works erected, to keep up sufficient depth of water for lighters and other vessels to pass. By the proposed alteration, the Lagan navigation can only suffer the same inconvenience it at present experiences during the summer months. The constant summer-level would, perhaps, require an additional lock, which, no doubt, would obviate any inconvenience it might suffer, from the proposed alteration in the winter-level of the lake. While these works are in progress of execution, the necessary works on the new channel through the Crea, to regulate the surface of the lake, might be carried on. In order to regulate the altitude of the lake, the new outlet should be furnished with flood-gates, which should be kept closed whilst the waters remain at summer-level. There should be also a regulating waste-weir at the side of the sluice-gates. This contrivance would have the effect of discharging the water the moment it rises above the summer-level, by raising one or more of the gates to produce the necessary discharge, and thereby keep the surface of the lake at the desired altitude; which being fixed and certain, would afford security, and encourage further improvements. The proprietors of the eel-weirs at Toom and Portna, should get adequate compensation for any loss they might sustain from the proposed alteration; but it is my opinion that these will suffer very little injury by the alteration, as the new state of the river might be as favourable as the present, and perhaps more so; it being a well known fact, that the overflowing of the river, when the eel-fry is ascending, has the effect of disseminating great quantities over the adjoining lands, where they are lost. The water being confined, and the obstructions removed, the fry can make its way into the lake unassisted by artificial means, by which the expense of keeping people, for months, attending with straw ropes to assist them up the rapids, will be saved, and the entire of the fish secured. By the proposed plan of drainage, sixty thousand acres of land would be improved, which might be converted into good arable land; as after the proposed alteration having been effected, all the bogs and flooded lands in these districts, which are now of little or no value, would then command a sufficient fall for their drainage. The works at the Salmon Leap, Laughans, Moyvannaher, and the Vow, might be deferred till the others are completed, or till an act of parliament was obtained, to enable the company to open the navigation of the entire district, by means of a canal through the Lower Bann—an object very easily effected, and much to be desired. I have been induced to recommend the postponement of these last works at the Salmon Leap, Laughans, and Vow, from a conviction that the quantity of land gained in their immediate vicinity, would, by no means, be commensurate with the expense." See the Ordnance Maps of the lake and surrounding country.

Previously to our being employed as engineer for the drainage of this vast lake, numerous engineers of eminence had given plans and estimates for effecting the same; and it is a remarkable fact, that they all agreed as to the dimensions of the cut necessary to carry off the water, so as to keep the surface at summer-level, making the breadth one hundred feet, and its depth seven feet. The following calculations, however, founded on the same data, make the required dimensions three times as great:

Let a=area of the lough.

$b=\left\{\begin{array}{l}\text{height of inundation above the ordinary level}\\ \text{of the lough, caused by the floods in 24 hours.}\end{array}\right.$

$h=\left\{\begin{array}{l}\text{depth of proposed cut below the ordinary level}\\ \text{of the lough, in order to preserve that level}\\ \text{during the floods.}\end{array}\right.$

x=breadth of proposed cut.

$g=\left\{\begin{array}{l}32\frac{1}{6}\text{, being the velocity produced by gravity}\\ \text{in a falling body, at the end of one second of}\\ \text{time.}\end{array}\right.$

Now it is evident that the depth multiplied by the area, gives the volume of water to be discharged in a given time; therefore we get ab=volume of water to be discharged during 24 hours, and this volume or quantity divided by the number of seconds in 24 hours, will give the quantity of water to be discharged in one second of time; that is,

$\frac{ab}{86400}$=volume to be discharged in one second. Again, $(2gh)^{\frac{1}{2}}$= velocity per second produced by gravity in a body falling through a height equal to the depth of the proposed cut (see Gregory's Mechanics, vol. i. book 2, page 188, art. 243.) = velocity of water rushing through the lowest part of the proposed cut.

$\frac{2}{3}\times(2gh)^{\frac{1}{2}}\times hx$ = volume of water passing through the proposed cut during one second. See Gregory's Mechanics, vol. i. book 4, page 411, art. 441.

The quantity of water over the summer-level, and that passing through the cut, must be equal; for if more water, during a flood, comes into the lake than the cut was able to discharge in the same time, it is manifest that the surface would rise by the amount of the difference: therefore we have,

$\frac{ab}{86400} = \frac{2}{3} \times (2gh)^{\frac{1}{2}} h x$; or $x = \frac{3}{2} \cdot \frac{1}{86400} \cdot \frac{1}{(2gh)^{\frac{1}{2}}} \cdot \frac{ab}{h.h^{\frac{1}{2}}}$ or $x = \frac{1}{57600} \cdot \frac{1}{(64\frac{1}{3})^{\frac{1}{2}}} \cdot \frac{ab}{hh^{\frac{1}{2}}}$, the required formula, and $hx = \frac{1}{57600} \cdot \frac{1}{(64\frac{1}{3})^{\frac{1}{2}}} \cdot \frac{1}{h^{\frac{1}{2}}} =$ section of cut.

Here $a = 97000$ acres $= 4225320000$ square feet.

$h = 7$ feet, this being assumed as sufficient depth.

$b = 6$ inches, the increased height of the lake in 24 hours, as actually ascertained.

Then $ab = 4225320000 \times .5 = 2112660000$, $(64.3')^{\frac{1}{2}} = 8.0208$, and $7^{\frac{1}{2}} = 2.645$; then $2.645 \times 7 = 18.515 = h\,h^{\frac{1}{2}}$.

Hence $x = \frac{1}{57600} \times \frac{1}{8{\cdot}0208} \times \frac{2112660000}{18.515} = 246.9$ feet. Then making allowance for the vena contracta and friction, this breadth must be increased to 300 feet at least.

To solve the same problem on different principles.—Let us suppose the lake to be full, and that we require the time to empty it by means of a cut from the top to the bottom of it.

Let $x =$ variable height of the descending waters of the lake.

$b =$ breadth of cut, which we shall suppose given.

$d = \left\{ \begin{array}{l} \text{depth from lower part of cut to upper surface} \\ \text{of water, when the lake is inundated.} \end{array} \right.$

$A =$ surface of the lake.

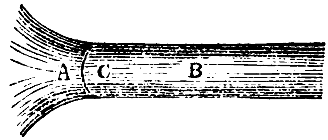
$g = 16\frac{1}{12}$ feet, the descent by gravity in one second.

Now, the velocity at the lowest part occasioned by gravity is $2\sqrt{gx}$; therefore, $2\sqrt{gx} \times bx \times \frac{2}{3} = \frac{4}{3}\, bx\,\sqrt{gx}$ = quantity of water discharged through the cut in one second of time. This last quantity divided by the area of the lake, will give the velocity of the descending surface of the lake in one second; that is, $\frac{4bx\sqrt{gx}}{.\,3A}$ = velocity of descending surface of lake per second. But uniform descents are as their times; therefore,

$\frac{4bx\sqrt{gx}}{3A} : x' :: 1'' : \frac{-3A\dot{x}}{4bx\sqrt{gx}} = \dot{t}\,\dot{t}$, the fluxion of the time of descending.

Now, if we suppose the surface of the lake to be constant, which is very nearly so, the correct fluent of this fluxion is,

$t = \frac{3A}{2b\sqrt{g}} \times \frac{\sqrt{d}-\sqrt{x}}{\sqrt{dx}}$ = general time of sinking the lake to any depth x. From this equation we get $b = \frac{3A.(\sqrt{d}-\sqrt{x})}{2t.\sqrt{gdx}}$. Here, by the assumption made in the beginning, b is the required quantity, and all the quantities on the right hand side of the equation are given: that is, in its application to the cut at Lough Neagh, $x = 7$ feet, $d = 7.5$ feet, for the surface of lake rises .5 foot in 24 hours, in times of high floods; $A = 97000$ acres, $g = 16\frac{1}{12}$ feet, $t = 86400$ seconds; but as height of cut is not d, but x, the value of b requires correction. The velocities being as the square roots of the heights of cuts, the value of b varies inversely as $\sqrt{d} : \sqrt{x}$; therefore $\sqrt{x} : \sqrt{d} :: \frac{3A.(\sqrt{d}-\sqrt{x})}{2t.\sqrt{gdx}} : \frac{3A(d-\sqrt{dx})}{2t.\sqrt{gdx}}$ = breadth of which agrees with the foregoing, very nearly.



In the annexed figure, A is the lake, B the intended cut, and C the gate to regulate the surface of the lake, so as to keep it at summer-level. The works at C are circular, that form of gates being capable of resisting a greater pressure from the side A than straight ones.

When a sufficient fall cannot be had for the drainage of a lake, or when the making of a cut becomes too expensive, then the drainage is effected by pumping the water over the marginal barrier surrounding the lake. Some lakes have been drained by opening a subterraneous tunnel from the nearest outlet to the lowest part of their bottom, giving it a sufficient slope to carry off the water.

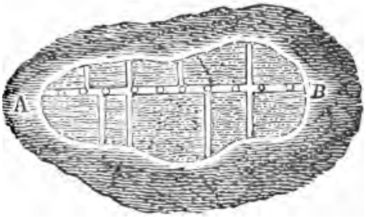
There are many instances which might be adduced, to show the benefit derived from draining lakes: among them may be mentioned that of a lake situate near the road from Dromore to Waringstown, in the townland of Ballycross, formerly part of the estate of Chichester Fortescue, Esq., and purchased some time since by the Marquess of Downshire. "His Lordship's attention," says the Newry Telegraph, "was directed to the practicability of draining this lake, from the evidence which its vicinity bore to an attempt to effect it having been made and failed. A deeper cutting was to be made, and an outlet obtained thereby, although the difficulties of distance, as well as an intervening rock, presented formidable obstacles; the result has proved the propriety of the undertaking. The land covered with water was rather more than thirty acres, statute measure. To lay it dry, a drain has been made, nearly three quarters of a mile in length, averaging ten feet in depth, and thirteen feet wide; considerably more than 100 perches of which was entirely through a rock of hard whinstone. This operation was begun in 1837, and finished in 1840, at a cost of £800, and a consumption of upwards of 1000 lbs of gun-powder. The operation was slow, because of the impediment the rock presented. The result of it is stated to be the entire reclaiming of more than 30 statute acres of bog, now laid dry to the depth of 10 feet; thereby affording a cutting of the best description of turf (a most valuable article in this district) over the whole surface, upon an average of seven feet, yielding an income, for the next seven years, of about £150, thereby repaying the outlay and interest at the end of a little more than six years, being a return of about £17 per cent.; and ultimately the same quantity of good meadow land, in perpetuity, at a rent of at least a pound an acre. The advantage to the neighbourhood does not rest here. By draining this lake, the benefit is extended to the adjoining lands and the tenantry; and its vicinity is relieved from the great evils arising at all seasons from a stagnant pool of water. A similar operation is in progress upon the river bounding the estates of the Marquess of Downshire and David Ker, Esq., near Ballynahinch; where, by a heavy cutting through rock, and diverting a portion of the course of the river, the water in it will be lowered six feet, and a large tract of bog, in wet seasons of very little use, will be laid dry; and the adjoining meadows also much benefited by the draining. It is, of course, at the joint expense of both proprietors. The advantage that will be derived by this last operation cannot as yet be specifically estimated, but there is no doubt it will be very great, both to the landlords and their tenants. It has often occasioned surprise that similar works are not oftener undertaken. There are nearly every where many loughs and bog-holes, the contents of which, whether turbary, marl, or land, would, if well drained, pay well for the outlay, in money and land, as well as in healthfulness to the district, and employment to the peasantry."

Land-locked Bogs or Morasses.—Besides lakes, there are numerous basins containing stagnant water, not produced by springs, but merely by rains descending down the sides, and resting on an impervious subsoil. Such bogs or morasses are very common in many parts of Ireland. Many of these are so low, as compared with the surrounding country, that their drainage, by means of a cut, is either impossible or too expensive; therefore, the water must be carried downwards, by perforating the impervious bed of clay on which it rests. When this retentive stratum rests on a porous one, or upon a rock with fissures, the drainage may be effected by perforation; but when the under stratum does not absorb the water passing through the perforated stratum, the drainage, by this method, must be abandoned.

It sometimes happens that water ascends through the perforated stratum, as in Artesian wells; and when this is the case, the drainage by perforation must be abandoned. When the quantity of water is not great, and the ground circumstanced as in the two last cases, the best plan would be to cut deep and capacious ditches along the lowest part of the morass, raising the adjacent parts by the amount of the stuff excavated.

These deep cuts collect and retain all the water, leaving the banks sufficiently dry for pasture or meadow, and checking the further growth of moss. When the drainage is effected by boring, the drains are to be cut very narrow, and covered over with small loose stones, to within a foot and a-half of the top, otherwise the auger-holes would soon be choked by the sand and loose mud brought thither by the rain-water. The perforated drain should be made in the lowest part, towards which other drains should be directed; the number and extent depending on the quantity of land and water to be drained.

In the annexed figure, AB is the perforated drain, cut along the lowest part of the ground, into which all the water is conveyed by the cross-drains, as represented in the figure. If the water be found to ascend through the auger-holes, they must be closed up at once, to prevent further injury by an increased quantity of water from below. The cases in which boring answers are very few; the author never having seen a case himself, can only depend upon the testimony of others for their utility.



From what has been said, it appears evident that marshes or other low places, retaining water, may be drained in the same manner as lakes; but lakes containing much water, can never be drained by boring.

Drainage of low flat grounds, without any fall or outlet.—In situations presenting no natural fall or outlet, the process of draining and reclaiming becomes very expensive. There are two ways in which the drainage of such places may be effected. The one is by covering the surface with a sufficient quantity of stuff, drawn from some other locality, so as to raise it beyond the injurious influence of the water. The first layer laid on should be stones or gravel, to allow the water to pass freely, and thereby prevent its rising to the top, where it would be injurious to the pasture, crops, or buildings. This process may be seen in the neighbourhood of Dublin, on the banks of the Liffey. This method, however, is too expensive to be remunerative. It is never practised to any extent, except in the neighbourhood of a large town or city, where the land becomes valuable as building ground or town parks, or where the health of the inhabitants demands such improvements. The other method of draining such land is similar to that employed in draining the low lands in Holland. A certain portion is surrounded by an embankment, which is rendered perfectly impervious by puddling. Inside the embankment is cut a deep trench, to which the water is conveyed from the rest of the enclosure, and from this reservoir the water is pumped over the embankment. Open parallel drains are cut through the inclosed ground, all leading to the same reservoir, from which the water is bailed or pumped over the embankment, where it runs off. Should it be found difficult or expensive to convey all the water to one reservoir, then two or more may be sunk in some convenient locality, from which the water conveyed thither by the several drains may be easily pumped over the embankment. Windmills are frequently used for this purpose. In any case, the expense must be compared with the probable value of the land when drained, before the work commences. Without first calculating the probable return and outlay, the work might be productive of considerable loss to the undertaker. Drainage of this description is both expensive and difficult to be executed, therefore it should be commenced with due caution.

Open drains or ditches often answer the double purpose of conveying the superfluous water, and of enclosing the fields; they are, however, very dangerous fences, as cattle may be apt to fall into them, when unprotected by a bank, wall, hedge, or rail.

The Carse of Gardrie, a district in Scotland, containing about 30,000 acres of rich clay land, has been attended with, perhaps, unparalleled success. By mutual consent, the proprietors agreed upon the most eligible lines for cutting large drains from 15 to 20 feet deep, for conveying the water collected in them to the nearest accessible river. Ditches of small size were next drawn, surrounding and intersecting the farms, so as to serve for the divisions of the different fields, the water of which they collected and emptied into the large drain. The depths of these ditches were seldom less than four feet, their width at top six, and at the bottom from one to one foot and a half.

A vast quantity of land might be gained by the drainage of lakes in Ireland, all commanding such a fall as to render any expensive mode of drainage unnecessary; among the principal ones may be mentioned, Lough Neagh, Lough Foyle, Lough Corrib, Lough Swilly, Lough Mask, and numerous others of less extent

It is much to be regretted, that more facilities are not afforded to companies, and private individuals, for effecting so desirable an object as the drainage of lakes, bogs, marshes, and other waste lands in Ireland, by which the unemployed population might be supplied with constant work, instead of being thrown as a burden on the people. The reclamation of about three millions of acres of peat soil, (besides vast quantities of flooded lands and lakes,) which is the estimated extent in Ireland, may be effected without any additional expense to the community, by employing the idle poor, who must be supported in the poor-house, in "unproductive, and often mischievous idleness," at an expense too enormous for the country, in its present condition, to bear. It was hoped that the present drainage act, lately passed, would be productive of much good to the country; but in its present form, the landed proprietors do not seem inclined to take advantage of it: therefore, as it is found not to work well, it should be improved. Though the capability of red bog to produce crops, is, in general, over-rated, yet it will yield a good return on the outlay, by laying it out in meadow or grazing land. We have, no doubt, seen such land produce good wheat and barley, but very seldom. The ear very rarely fills, and the grain seldom ripens; therefore the tillage should be confined to rape, potatoes, oats, and rye, to any of which it seems to be well suited.

There are few countries in which draining and embanking, (draining especially,) would tend more to raise the condition of the labouring classes, than in Ireland; and while the poor would be benefited by getting employment, the proprietors would be largely remunerated for their outlay, by enhancing the value of their properties, in many instances, from five to ten fold. Martin Doyle, in his most useful treatise on husbandry, says:

"The immense tracts of our island, which are now unproductive from excessive moisture, among other causes, and which might be most advantageously reclaimed, unhappily prove, that many of its proprietors are as destitute of enterprise and anxiety to improve the condition of their tenantry, as they are blind to their own interest, and unawakened to the advantages which would result from a proper application of capital." Embanking very often not only improves the navigation by confining the water, but rescues from its dominion the richest soil for grazing and tillage.

Lakes and marshes are often converted into dry land by turning in the troubled waters of a rapid river or mountain stream, which will, in time, deposit such a quantity of alluvial soil, as will raise the bottom above the surface of the water. When this is effected the river or stream may be turned off, or allowed to pass through a narrow channel in the alluvian. The low flats on the Dee, Severn, Humber, and many other rivers in England, have been raised in the manner here described. The practice is quite common in Lombardy, Languedoc, and other places. In most places this process, though sure, would be found very tedious; but when a stream of water deposits alluvial matter on the surface of a bog, the good effects produced by it will in a very short time become visible; therefore, every available stream ought to be taken advantage of for the purpose of reclaiming bogs.

The want of roads in many remote districts in Ireland prevents improvement. Without roads to facilitate the carriage of manure, no improvement to any extent can be expected: patches here and there may be improved at a vast expense of time and labour, but nothing on a large scale can be attempted without a good road, or a canal, by which to convey manure. Therefore the first thing that ought to be done before commencing improvements upon an extensive scale, is to construct roads to the several points where the necessary manure may be had. These roads should pass through the bog at such distances as would render the carriage of the necessary manure convenient and easy. Good roads afford also easy means of transport of the produce raised on these wastes, without which, the expense of bringing it to market would be considerable.

EMBANKING OF RIVERS.

When a river overflows its banks in times of flood, or when it winds its way sluggishly through a very low flat country, it is often a work of some difficulty to confine it to its natural channel. There are only two modes of accomplishing it: namely, by deepening the bed of the river, and removing obstructions, or by raising its banks. Before commencing a work of this description, care should be taken that the advantages to be derived be greater than, or at least equal to, the outlay required to complete it. Improvements of this kind have been executed with great success, in many of the fens of England. Besides the land gained by means of embankments, the navigation is often improved, by which a double object is attained. In Ireland, thousands of acres of the richest alluvial soil might be gained on our rivers, and at the same time, their navigation rendered safe, by raising embankments, removing obstacles, and straightening the direction of the currents.

Capital might be advantageously expended in the improvement, by embankments, of the river Blackwater at Youghal, which would have the effect not only of improving the navigation, but also of taking in a considerable portion of land. The same observation applies to the river Slaney, at the town of Wexford, where a very considerable quantity of valuable land might be saved from the pernicious effect of the tide, which, at present, submerges it twice a-day. The navigation of the Belfast lough would be improved, by confining the water within narrower limits than it occupies at present, by which more land would be gained from the water than would pay for the entire improvement. By throwing an embankment from the town of Dungarvan across to the Rabbit-warren, it would prevent the tide from flowing over all that low district extending south-west of the town, all of which would be gained by the construction of this single embankment.

A few hundred acres of excellent land might be gained near the bathing town of Kilkee, and that fashionable summer resort rendered accessible to steam-boats, with a very small outlay of capital. We are surprised that those who are interested in the advancement and general welfare of this very thriving town, do not take active measures to enable steam-boats to approach it from the Shannon, which might be done at an expense so small, as would be trebly repaid by the land gained in rendering the approach navigable. This little town possesses natural advantages and capabilities, if improved by art, which would doubtless render it the most delightful watering place in Ireland. The river Fergus would be improved also by means of embankments, which would prevent the water from spreading and injuring the land on its banks. The lands along the river Brick, in the county of Kerry, stand in need of similar protection from the autumnal and winter floods.

The Boyne, Deel, Upper Shannon, and a great many other rivers flowing through low meadow land, would require embankments in different parts of their course, by which the lands on their banks would be protected from the pernicious effects of the water, and enhanced in value to a degree commensurate with the outlay.

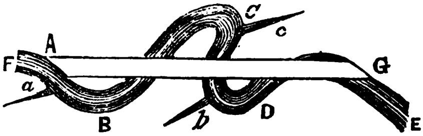
The improvement of Lough Foyle, by drainage and embankment, is progressing. It is expected that a large tract of valuable land will be ready for cultivation before the close of the ensuing year.

Judiciously formed embankments would be of great service in many places, where the water flows over the banks. These may often be executed at a trifling charge, by simply widening the channel, and raising the banks, using the excavated stuff for this purpose. An overflow is frequently prevented by keeping the bed of the river clear of weeds, bushes, shoals, or other obstructions.

When a promontory jets out into a stream, it should be removed, in order to give the current a more direct course, which facilitates its motion. The motion of the current is considerably retarded by flowing in a zigzag direction: therefore when a stream passes through the same property, its direction should be made as straight as circumstances would admit: and when a river separating two properties takes a winding course, the proprietors should agree among themselves to straighten it, taking care to give one party as much in one place, as is taken from him in another. This, besides giving the water greater freedom, will have the effect of preventing future encroachments, and give the respective properties a more sightly shape. The new cut should be sufficiently capacious to admit all the water to pass in times of flood, without overflowing its banks. The dimensions of the cut must be calculated upon some data founded on the particular case under consideration.

Without being guided by some principle in calculating the capacity of the required cut, you may make it too large, and thereby incur unnecessary expense; or you may make it too small, by which the water will overflow its banks, and perhaps resume its former indirect channel.

Where mills are erected on a stream or river, having a fall not exceeding six feet in a mile, the weirs thrown across them for the purpose of securing a supply of water, are very often productive of much injury to the adjoining fields. Such dams very often render it impossible to effect the drainage of the adjacent fields, and not only of the adjacent fields, but of other parts of the country far removed from the stream or river.



In this figure, the old channel is represented by the winding river A, B, C, D, E, which overflowed its banks in various places, especially at the abrupt turns B, C, D. The complete drainage of this might be effected by confining the water to the straight cut FG. If we suppose the old cut to separate two distinct properties, the new one should be made so as to cut away as much from one proprietor in one place, as he would receive in another; such improvements often prevent expensive and protracted litigation.

In forming an embankment, the slope depends on the nature of the stuff employed. There is one thing, however, certain, that is, that the greater the slope, the stronger the embankment. From one foot and.a-half to two feet on each side, for every foot in depth, is found, in most cases, to be sufficient.

Every embankment should be covered with sods, or sown with grass seeds, to prevent them from injury. When the current is rapid, the base of the embankment should be protected from its influence by large rocks, or by building it of solid masonry, if the advantages gained warranted the outlay. This, however, is seldom required, the velocity of the water, in most places requiring embankments, being generally very slow.

It will be useful to know, that when the river stream acquires a velocity, at the bottom, of three inches per second, "it will begin to work upon fine clay, fit for pottery; a velocity of six inches will lift fine sand; eight inches will lift sand as coarse as linseed; twelve inches will sweep away fine gravel; twenty-four inches will roll along rounded pebbles an inch in diameter; and it requires three feet per second at the bottom to sweep along shivery angular stones of the size of an egg."

DRAINING OF BOGS.

Before entering upon the method of draining bogs, it may not be uninteresting to give some account of their formation. It is a strange fact that peat bogs should be classed with the alluvial soils, the former being obviously a vegetable production, whose growth, however, is soon checked by the recent improvements in agriculture, which have had the happy effect of converting numerous bogs and marshes in various parts of Ireland into arable land, covered with luxuriant herbage and depastured by numerous flocks. It is however much to be regretted, that the system of improvement in this department is not more extensively adopted. The production of peat, when not completely under water, is confined to places containing water, where the temperature is so low as that vegatables may decompose without putrefying.

The peat bogs of Ireland consist of numerous plants, but especially of a species of moss (sphagnum palustre,) which has the property of throwing up new shoots in its upper parts, while its lower extremities are decaying. Professor Wade says, "it is well known that all boggy grounds are not only thickly covered over with mosses, but that in a half-decayed state they in a great measure contribute to their solidity, for it is not from mosses alone that turf is derived, even whole trees form the composition of turf beds.

"The bog moss (sphagnum) in its different appearances of whitish yellow, rose color, and green, appears to be the most predominant, and performs the chief share in the generating of turf bogs. The great golden-hair moss (polytrichum) seems to be the next. Many species of feather moss (hypnum); thread moss; (bryum); spring moss (mnium); besides many other kinds, lend their assistance.

“ The geographical extent of mosses is very remarkable, and appears to be rather interesting. We find them on the southern sides of the most barren rocks ; likewise in other sunny situations ; on pure dry sand, on bare quartz, on rocks of porphyry and granite, on calcareous rocks, on slate, on gypseous soils, on the sides of pit coals, argillaceous soils, &c ; even rivers, brooks, and springs afford several species ; and it is very remarkable, that they grow very luxuriantly on soils which contain iron ochre or marcasite.

“ Mosses appear to require a much lower temperature, and a more rough climate, than most other vegetables. Their most vigorous growth and propagation are in the spring and autumn. In low situations they are seldom or never seen in the middle of summer, heat impeding their vegetation. It is observed that in polar regions, where the snow never thaws more than a few inches deep, mosses and lichens are the vegetable productions only to be met with. It is remarkable that the power of elongation, which is very striking in many of the mosses, which for the most part are perennial, does not so much belong to their roots as to their stalks and creeping branches ; and I am inclined to doubt whether any of the moss tribe are annual, and propagated by means of seeds only. The leaves of mosses never drop off at certain periods, but generally remain as long as the stalks and branches. It is by no means the case, as generally supposed, that mosses impoverish the ground on which they grow ; they grow best in barren places, and love cold and moisture ; hence they cover those lands with verdure, which would otherwise remain bare ; and so far from injuring the plants which are found growing with them, they afford them protection, their roots penetrating to so shallow a depth into the ground, that they take from it little nourishment. Wherever a small quantity of grass is seen with mosses, there would be none without them; and if the land is drained and aptly manured, it will be seen that the moss is no impediment to the growth of the grass, for the moss soon disappears, and the grass flourishes. Mosses retain moisture for a length of time, without rotting, which is a quality worthy of attention in many points of view; and it is singular that no moss has been discovered liable to the attack of insects or worms."

Doctor M'Culloch states that peat is intermediate between simple vegetable matter and lignite, being very gradual, and brought about in the lapse of time, by the prolonged action of water. A cold climate is essential to the growth of peat. Therefore, bogs are seldom, if ever, found within the tropics. It abounds more as we recede from the equator. A vast extent of the surface of Europe is covered with peat, and in Ireland it is said that the tenth of the entire island is covered with it. This is an assertion, however, that we cannot of our own knowledge state as a fact. It is a fact, not more curious than it is true, that many of the bogs in the north of Europe occupy the place of immense forests of pine and oak, many of them having disappeared within the historic era. " Such changes are brought about by the fall of trees, and the stagnation of water caused by their trunks and branches obstructing the free passage or drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate, such decayed timber would immediately be removed by insects; but in the low temperature, now prevailing in our latitudes, many examples are recorded of marshes originating in this source."

Doctor Rennie says, that in Mar Forest, in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immersed in peat, formed partly out of their perishing leaves and branches, and in part from the growth of other plants.

In the seventeenth century, the overthrow of a forest in Rosshire, gave rise to a peat-bog, which was cut for fuel after the lapse of the very short space of fifty years.

It is an opinion very generally entertained, that most of the peat-bogs of Europe are not more ancient than the age in which Julius Cæsar lived. We have no doubt that many of the bogs of Ireland, are not of on older date than Henry the Second's reign, when extensive forests were cut down, by his orders, to prevent the Irish from taking shelter in them, and harassing his troops.

" When a quantity of oak leaves, or bark, or wood, or even aquatic plants, drop into a pond of stagnant water, a change of color ensues, and it acquires a bitter astringent taste, and antiseptic quality. Aquatic plants, such as abound in moss, may flourish, even in such a liquid, though no succulent herb will. By this means a mass of vegetable matter may be accumulated, and in the course of ages that matter may be converted into moss."

Having said so much on the formation and properties of peat-bogs, we shall now consider the best mode of preventing their growth, and also of draining and cultivating them.

Any one who takes the trouble of examining the mechanical causes that facilitate the formation of peat-bogs, will see that their growth is prevented by running water, as the banks of all streams which traverse them are clothed with green succulent pasture, when the velocity of the water is tolerably rapid; but when the velocity is slow, the bog grows on the water's edge, not, however, to such a depth as at a greater distance. And though a stream of water, with a given velocity, prevents the growth of bog, yet water gliding along a given slope does not prevent its growth, as nothing is more common than to see a bog extending from the base to the top of steep mountains, which proves that water percolating through the soil down the slope, does not prevent its growth. Neither is the mere drainage the only cause of the grassy borders of the stream, as is justly observed by Mr. Nimmo, in his bog reports, since we see the edges of the turf-banks, although certainly dry enough, so far from affording pasture, are the most sterile spots that can be pointed out in the whole bog-field. The edge of the banks of those streams which cut deep into the soil, are also covered with heath only; and the same thing may be oberved of artificial ditches or drains. In this last, however, we frequently see good grass on the stuff which has been thrown up from the bottom, and some time exposed to the weather.

From what has been said, it is obvious that bogs cannot be reclaimed by draining them thoroughly; as when deprived of all moisture, the soil produces nothing whatever; neither will it answer to allow them to remain submerged for any time in stagnant water. Therefore, to reclaim bog, the most economical plan appears to be that pointed out by the natural operation of running water; namely, to irrigate the surface, after having drained it sufficiently. With respect to the direction and position of the drains, you must be guided by circumstances.

If the water be supplied by springs, issuing from the side or base of a mountain, or from any other ground higher than the bog, the supply may be cut off by cutting a drain along the upper margin of the bog, and connecting it with a main drain leading to the lowest point of discharge at the bottom of the bog, where, in Ireland, there is generally a river or brook, capable of carrying off all the surface-water, at least, of the entire bog.

The capacity and number of these drains will depend on the extent of the bog, and the quantity of water to be drained off. The catch-water drain at the foot of the hill may be cut one foot into the firm subsoil, in all about four feet deep, five feet wide at top, and two feet at bottom. The bog is then to be divided into divisions, each containing as many acres as may be covered with water one quarter of an inch, at least, in depth, from the catch-drain. The water in this drain may be turned upon these enclosed divisions, by building small weirs at short distances from each other, across the drain, which will have the effect of diverting the course of the stream in the catch-drain. The water which irrigates one plot of ground, may be employed to perform the same office in the next plot lower down; so that the entire may be laid under water at pleasure. Should the irrigating waters bear with them a quantity of gravel, sand, or slime, the effect will be beneficial. The mechanical contrivance necessary to effect this, will be given in the article devoted to irrigation.

The bog being now tolerably improved by drainage and irrigation, a still further improvement may be effected by top dressing it with limestone gravel, shell sand, lime, or marl, whichever the locality produces, mixing it up with as much vegetable earth as can conveniently be procured in the vicinity of the bog, all being sown with grass seed. Very few bogs, in Ireland, are so circumstanced as not to command a sufficient fall for their drainage, but many of them are too flat to be irrigated to advantage. Sea-sand, lime-stone, gravel, lime, marl, or vegetable earth, may be procured within a reasonable distance of almost all the bogs in the country, which, if treated in the manner here described, may be converted into rich meadow or pasture, equal in value to the best land in the island. The drains should be kept clear, and never allowed to choke up, otherwise the effects of the improvement will, in a few years, be scarcely visible.

Bogs may be converted into arable land by tillage. The method adopted, by small farmers, in the bog districts of Munster and Connaught, to reclaim those wastes, seems to answer very well. The general practice seems to be to plant potatoes in ridges, manuring with sea-sand, sea-weed, or lime and dung, whichever is most cheaply obtained. The beds should be four or five feet wide, the furrows answering all the purposes of regular drains. It would be well to burn a quantity of the stuff thrown up on the beds, if it should produce red ashes, which make good manure; but when white ashes are produced, burning is useless. In such ground, the second year's crop is much more abundant than the first; the third year's crop may be oats, with perennial grass seed, which being cut for hay next year, will leave the ground in tolerable meadow.

There is another method employed in many parts of Scotland, to convert bogs into arable land. "The bog is simply trenched over with the spade, to the depth of 18 inches or two feet, taking care to shovel out the bottom of the trench quite smooth and clean; the sods are turned with the heath side down, and the black bog, which is turned to the surface, is well pulverized with the spade, &c. There are also cut in the solid bog, small trenches or gutters, running obliquely down the slope, and collecting in a furrow or surface open drain. The heathy turf which covers these small gutters, prevents them from filling, and the whole process produces a very general under-draining: the bog in a short time becomes covered with chicken-weed, and soon after produces a tolerable meadow." It would be better to run the drains right down the slope, as shall be shown hereafter.

Though the admixture of foreign soil is favourable to the cultivation of bogs, yet it is not to be considered as absolutely necessary; good crops being raised on red bog by forming it into beds of three or four feet wide, and spreading sea-weed on them in spring. In May the seed potatoes are spread on the sea-weed, and covered over with small sods of red bog from the trenches, which, as we said before, act as drains. In the month of June, the sods are all hacked small with the spade, and a fresh supply of wet stuff from the trenches put on, which protects the seed from the effects of the sun and air. Without thus pulverising the bog stuff, the sods would soon contract from drought, and become perfect turf, incapable of producing vegetation of any sort.

Though bog is known to produce good crops without any admixture of foreign stuff, yet a small quantity of calcareous matter, or even clay or vegetable earth, would be found of considerable benefit.* Caustic, or quick-lime, is an excellent manuring agent for boggy soils, as it possesses the power of quickly dissolving the vegetable substances with which it is placed in contact. And though lime in this caustic state answers best for bog, yet it is improper for upland, and especially when used as a surface dressing on grass. It should be mixed with clay, or lime-stone gravel, if possible.

When upland is overrun with noxious weeds, this lime may be used, which will have the effect of destroying them. Thirty or forty barrels of lime are considered by some farmers sufficient for one acre. It is considered by chemists, that magnesian lime-stone, when rendered caustic, is perhaps superior to common caustic lime for improving bogs, its effects being more lasting. Tenacious blue clay, frequently found under bogs, makes an excellent manure, when exposed for some time to the influence of the atmosphere.

When lime is used as a fertilizer for red bog, it should invariably be mixed with some foreign soil; or the surface may be first covered with vegetable earth or clay, over which the lime may be spread.

It has been mentioned before, that a river or stream generally runs through or by the side of most of the

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* Whatever is capable of feeding, or of supplying food to the plant, may be considered as a manure. Lime in a state of carbonate affords food to the plant, and serves to convey other food to the roots, in a state fit to promote vegetable growth.

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as two hundred, or two hundred and fifty acres. Parallel drains, however, are better to carry off the water.

When the bog is of considerable extent, the most economical plan would be to run a road through it, and reclaim the narrow strips on either side, along which fresh drains might be made, parallel to the road, which will prepare two other portions for reclamation; and thus you may proceed, receding from the road, and making further encroachments on the bog.

By adopting this mode, all the parts of the bog are rendered accessible to carts at a comparatively small outlay in the way of drainage. The dimensions of the drains depend on the quantity of water to be drained off. In red bog, the drains are apt to collapse, in which case they must be reopened. The water in these drains should not be far below the surface of the bog, as otherwise it might be drained too much, in which state it would produce nothing. But when the soil consists of a black peaty mould, it makes no matter how dry it is, provided it be sufficiently pulverised and manured.

It would be well to plant a belt of Scotch firs around the inside of the circular drain, or along the road-side, for the purpose of affording shelter.

Planting should never be neglected in reclaiming bog land. Mr. Burrough recommends the common rotation, commencing with rape, then potatoes, with oats following; after which it may be sown with grass seeds. The grass should be cut the first year, and no heavy cattle allowed to feed on the ground, till rendered sufficiently solid by a top-dressing of clay, marl, gravel, road-scrapings, or some other suitable material.

In draining a deep bog, the principal drains should be left open, and all the cross or minor ones may be covered over by a reversed sod, resting on two shoulders, left on either side of the drain. This reversed sod may then be covered over with peat. These minor drains must be of sufficient depth, so as never to be injured by the operation of ploughing or digging.

In making deep drains through a shaking bog, care should be taken not to cut to the entire depth at once, as if done too quickly, it would be liable to close up; therefore, after cutting it about one foot deep, it should be allowed some time to consolidate; then it might be cut deeper, giving it time, as before, to acquire such a degree of firmness as to keep it from closing up.

Mr. Stephens recommends the main drains in an extensive bog, to be cut to the depth of five or six feet, and "where this depth does not reach to the bottom of the moss, or to the stratum containing the water, bore-holes or wells must be made in their bottom, through which the confined water will rise by its own pressure to the bottom of the drain, so that it will be reduced to the same level.

The bore-holes are made with an auger about five inches in diameter; but when the moss or peaty earth is so soft that they will not keep open, wells filled up to the bottom of the drain with small stones must be made." The bog being drained, Sir John Sinclair recommends paring and burning, "as it is difficult to improve them without the process of paring and burning." He further states that "it is not easy to keep it in an arable state without the assistance of fire." This, however, is not the case.

Mr. Reid, author of a well written prize essay, "on the draining and cultivation of moss, and other waste lands," says that "the great stumbling-block to the road to success, seems to have been the want of duly considering the principle by which the water is retained in mosses. In many instances much labour has been thrown away, in endeavouring to cut wide and deep drains, at considerable expense, under the impression that they would produce every desirable effect over a large extent of surface; but, without saying it is absolutely impossible, it may be safely asserted that it is very unprofitable, to attempt even to cut deep drains on white or flow moss; the semi-fluid character of this substance, in consequence of the quantity of water held in the multitude of capillary tubes of which the vegetable mass is composed, causes a pressure upon the sides of any and every drain that is cut, and the pressure will be as the depth. The water, in fact, seeks to find the lower level, which has been created by the drain, but it is held in the moss by capillary attraction; a sort of conflict then ensues between the two principles, which in all cases, when the drain is made of an improper depth, ends in the water taking the moss along with it, as it were, and the two sides of the drain come together." We have seen this verified in numberless instances, where very deep drains, cut hastily, at considerable expense, collapsed in a very few years, from the cause assigned by Mr. Reid. And besides the danger of their closing up, when cut too deep, the object, if attained, may not prove advantageous, as no more than the surface water need, perhaps, be carried off. "Both principle and practice have taught and confirmed the author in the opinion, that the only effectual way of draining deep moss, is by inserting drains at small distances from each other; and that in order to effectually drain, and at the same to keep the expenditure within a proper compass, it is necessary to make the drains of as great a depth as the moss will conveniently allow, without removing more of the moss than is absolutely necessary." We have seen many instances of bog improvement, in various parts of the counties of Cork, Kerry, Clare, Limerick, Tipperary, and Waterford; and the plan pursued in all these places was somewhat similar. The drainage was first effected; then the surface was pared and burned, (in deep bog,) and next it was tilled, manuring with sea-weed, sea-sand, limestone gravel, or lime. In every case, except where sea-weed was employed, dung was added to, or mixed with, the other manure. The first crop was potatoes, rape, or cabbages, all of which grow well in such soil. The most important bog improvement in Ireland, has been effected on the estates of Lord Clonbrock and Mr. Fetherston H.

These spirited proprietors have set an example which ought to be followed by others possessing estates with large tracts of mountain and bog wastes, which, if judiciously managed, might add considerably to their present rent-rolls. These improvements have been attended with so much success, and have brought so remunerative a return upon the outlay, that the plan adopted in making them, deserves particular notice. This plan cannot be better described than by giving a part of the report of a deputation that went to inspect Mr. Fetherston's improvements, at the request of the

Agricultural Society of Ireland. The deputation consisted of Sir John Burgoyne, J. L. W. Napier, Hugh M. Tuite, Charles Hamilton, and Charles William Hamilton, Esqrs. The report, after some preliminary observations not uninteresting, states that—

"Mr. Fetherston commenced his work in the spring of 1832, upon the townland of Raton, situated about two miles and a half west of Kinnegad, in the county of Westmeath. In external appearance the bog presented little to attract speculative enterprise, being of the wettest character, and utterly unproductive; a mere tract of black slime, studded with tussocks, hags, or little elevated islands, upon which stunted heath barely vegetates. In accompanying circumstances the district is more highly favoured, as it shares, with almost every other bog in Ireland, the vicinity of lime-stone and lime-stone gravel. The lime-stone is met with in boulders. The lime-stone gravel deserves more attention, as it is either not found, or not generally known in either Scotland or England as an amendment; but it is both well known, and occupies a considerable place, in the agriculture of Ireland.

"It is a hard sort of calcareous marl, that assumes the appearance of small stones or gravel, when spread upon the ground or mixed with it, gradually falls into smaller pieces, and fertilizes the soil in proportion as it breaks down, or mixes with it.

"With reference to agriculture, the bog may be divided into two classes: the high red bog, which forms the great mass, and which burns away, giving very little ashes—and the black peat, which is found on the low edges, and which, when burnt, gives a large pro-

the sides to harden, and when this object is effected, the drain is cleared out, and a second cutting with the spade and scoop effects another opening at the bottom of the former one, seven inches wide, and one foot six inches deep. The first or upper sod is then placed so as to rest upon the shoulders of the under drain, and the remainder of the sods are filled in over it; during these operations the workmen are obliged to wear pattens, to support them on the soft moss; it is hard work, and requires strong and well fed labourers.

"Mr. Fetherston's practice has hitherto been to leave the cutting of the drains to be done by day's work, the anxiety in the men to prove themselves good workmen, and thus entitle themselves to promotion, being a sufficient stimulus to exertion; but there would be no difficulty in arranging the value of the work by the piece. Mr. Reid's opinion, upon the effect of the industry thus encouraged, is worth quoting. He says:—

"'It appeared to me, when last at Griffinstown, that although you had so raised the wages of the men who worked upon the bog 20 per cent., you got 50, or in some cases 100 per cent. more work done by each man per diem; here is a direct profit both to you and the men; and who will say where the incentive to exertion in others, which is furnished by this example, is to end?'

"The drainage having been thus completed, the next operation was to level any great irregularities with the spade, and immediately introduce the plough to turn up the whole surface. The plough is made very light, of wood, shod with sheet iron; it is drawn by one horse, that has pattens affixed to his feet; the horse is easily trained to wear them, by turning him out to grass for a couple of days with the pattens on. When the plough has done its duty, it is followed by a roller, made of iron, with plates of thin iron, six inches deep, set at five inches apart, at right angles to the cylinder and wheels, which are taken off when the roller is used. This, passing backwards and forwards over the roughly turned up sods of turf, reduces them, and, as it were, minces them so fine that no large clod is left. Then comes the use of the railway, each length of which consists of two iron bars, connected by cross bars of round iron; the side bars are fastened upon triangular wooden beams, which enables them to rest upon the soft bog. The railway is laid from the place where the gravel is to be raised, and which of course is selected, where the double purpose may be gained, of either sinking a main drain, or making some necessary excavation in the bog. The waggons are then placed upon the railway, and one horse draws about three tons; they are delivered at such a distance as may enable the shovellers to distribute the gravel to the depth of about 3 inches, for about 5½ yards on each side of the railway; which, when so far is completed, is moved 11 yards further on one side, and the operation continues until all is covered; if 12 waggons are discharged to every 24 feet of railway, it will take 1068 loads to the Irish acre. The plough is then used, or not, according to circumstances.

Mr. Reid says, "'If you work the bog right well before you apply the gravel, there is no doubt you can do without ploughing afterwards, if it is to be sown with grass seeds; the object is to mix the bog and gravel, and so as that is done, and well done, it is no matter how; only the least troublesome way is the cheapest, and, therefore, the best.'

"The bog is then either laid down with grass seeds, or manured with dung or ashes, principally the latter, for a crop of potatoes, followed by oats or bere. Mr. Fetherston's practice has been, to lay down immediately with grass, which he feeds off with sheep. The seeds used are chiefly Timothy, Cocksfoot, and Ribwort. Rape has been tried, but it has been found to injure the after-crop of grass materially.

"This portion of the improved bog has been gradually consolidating. During the last year, one and a half-year old bullocks have been fed upon it, without injury to the surface; and there is every reason to expect, that in a little more time it will prove as firm and solid as any of the surrounding land, at least as far as the purposes of the grazier are concerned.

"In the next portion, undertaken in the spring of 1834, some considerable improvements were made. It was found that the bog could be drained from the surface as completely as by the system of covered drains, and thus a saving of labour to a great extent was coupled with a more lasting character of improvement. Open drains were laid out, at about 70 or 80 yards apart, and the intervening space was thrown into inclined planes, irregularly enough, as advantage was always taken of the natural lie of the bog; but in such a manner as that the water falling on the surface should readily discharge itself over the surface into the open drains. This mode has proved perfectly successful; a fault too in the former mode was corrected.

which is little injured, and upon the greater cost of labour at the beginning, when the labourers were inexperienced, and the mode adopted more expensive than that which has recently been found equally or more effective. By taking the minimum of expense, and maximum of value, which is, perhaps, the fairest way, example being before their eyes, it is in the power any one to do so now in practice—the return will about 14 per cent.

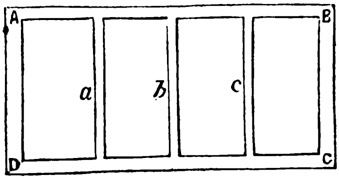
Fetherston thinks that the uses to which he the railway upon his upland farm, in carting out drawing lime and turf, &c. &c., amply compensate the original cost of it; and he confidently ex- be able, by means of manure and lime, to keep improved bog in a state of perpetual meadow, by of course, its actual value would be greatly in- ed. The only question which now remains for us an opinion upon is, the durability of the im- ment. It has been said that bog will ever revert original condition of bog again; but we do not any reason to suppose, that a change should occur such a degree as to alter materially the value of the ulation. Even should it decline in productiveness a series of years, the gravel and lime are at hand, may be applied to, and worked into, the solid and rface, at a trifling expenditure."

Sinclair recommends paring and burning for ement of peat mosses and fens, "as it is dif- mprove them without paring and burning." ultural report of Scotland, states that "it is afterwards to keep them in an arable state, assistance of fire."

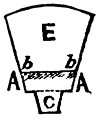
Mr. Bermingham, the active and intelligent agent of Lord Clonbrock, has been so successful in his bog improvement, that his practical plans of management must be the best example that could be selected for others to imitate. Mr. Bermingham has founded his method on Mr. Reid's practice at Chatmoss, and is admirably described in Martin Doyle's excellent work on husbandry, in the following words:

"He (Mr. Bermingham) divides the portion to be reclaimed into parallelograms, each containing three statute acres, 66 yards wide, and 220 yards long; these parallelograms are bounded by open drains, four feet wide at top, 14 inches at the bottom, and four feet in depth. Parallel covered surface drains, at average distances of 16½ feet, (the intervals are regulated by the state of the bog as to moisture,) are then cut at right angles to the open side-drains, and terminating in these at each end, so that if obstructions should occur towards one end, the water may flow off at the other. The width of these at top, is one foot six inches; and the depth to the shoulder, one foot ten inches; at the shoulder, is one foot two inches; and each shoulder is three inches wide, leaving the top of the hollow part of the drain eight inches in breadth; the hollow is fourteen inches deep, and six inches broad."

In the accompanying figure, A, B, C, D, are the open drains which enclose the portion to be improved; these drains are four feet wide; and *a*, *b*, *c* are the covered surface drains, whose distance apart is regulated



by the quantity of water contained in the soil; these are one foot six inches wide at the top.



The annexed figure shews the form of these covered drains, C being the hollow part, A A the shoulder of the drain, *b b* the inverted sod, and E the filling stuff. The drain here represented is cut with spades of different sizes and forms, each being made to suit a particular purpose. The top sod is first taken off and placed at one side, and the second then is cut and laid on the other side, and the next operation is, to cut the part C below the shoulders, after which the bottom of the drain is cleared with a scoop. All this being done, the top sod is laid upon the shoulders A A, giving it sufficient time to consolidate; and after a short time the stuff, E, is thrown in, which completes the operation. This is done at the small cost of one penny-farthing per English perch. The cost of the open drains is about five pence per perch. When the drains are finished, the next thing to be done is to level the surface with spades, filling up all the hollows with sods.

"Mr. Bermingham then recommends digging at all times in the first instance, in preference to ploughing, taking care that the surface should be dug down eight inches deep, perpendicularly, to prevent the workmen from merely skimming the bog, which, without being well watched at task, they are exceedingly inclined to do. The expense of digging is about £1 10s. per Irish acre.

"After this digging, before the gravelling takes place, while the bog is in a soft state, the sooner and oftener the cutter is applied the better, before the bog bakes into turf, as it will then have but little effect. The cutter, from the force of resistance, will require the power of four horses. This implement is composed of a number of circular knives, which being placed at short distances, parallel to each other, cut the sods into small pieces, so as to hasten the decomposition of the surface."

To prevent the horses from injuring the covered drains, they should, while the ground remains soft, be worked with pattens, which the animal can use after very little practice. When first put on, the horse should be turned out upon a grass field, where he will soon learn to walk with perfect ease to himself, with his pattens on.

After the surface has been rendered tolerably level with the spade, then a heavy roller may be applied, as soon as the state of the ground will bear it. Limestone gravel is then conveyed to the bog, by means of waggons moving on a rail-road laid down for the purpose.

"The total expense, including wear and tear, interest on capital, digging, draining, gravelling, manure, ploughing, sowing oats and grass seeds, has been £30 per acre—and varies according to the distance from which the gravel or clay is drawn." No one could think of reclaiming bog at such an enormous expense. Flow-bogs, difficult to be drained, and far from manure, could never pay for their improvement.

Mr. Bermingham uses lime and clay, or lime and the stuff raised in scouring the drains, as a top-dressing subsequently. Lime-stone gravel is considered to be the very best substance that could be applied as a manure, for the reclamation of any description of bog. Besides the first dressing, Mr. Bermingham applies 100 barrels of lime, mixed with clay, to every acre, before he crops, which is far too much. He does not recommend a corn crop in the first instance, being of opinion that rape, with grass seeds; or cabbages, turnips, or potatoes, to be followed by barley or oats, will answer much better. He also recommends the growth of rye-grass, as being well suited to such land. Worn out bog, with a small residue of peat, may be reclaimed at a much smaller expense than a deep one. In a bog or moor, having but a small quantity of peat, an admixture of the subsoil with the shallow covering, will prove of the greatest benefit. The subsoil, though considered by most farmers as the greatest enemy to vegetation, becomes, after exposure to the atmosphere, very productive; therefore no opportunity should be lost of mixing it up with the peat covering, wherever it is found within reach of the spade.

Bogs of every description are, however, more profitably employed for grazing than for tillage, and should therefore be laid down as soon as possible.

Bog land may be made to produce good grasses without much expense, by "spreading quick lime on the sward, without breaking it up." "In the course of two years the lime will convert the coarse herbage into sweet and excellent grasses for meadow or pasture."

Before the quick lime is applied to the surface, the bog should be completely drained and levelled. This mode of reclaiming, however, does not effect so permanent an improvement as tilling.

Mountain land, composed of black peaty mould, free from superabundant moisture, may be rendered most productive by merely breaking it up for tillage, using the manures before recommended for the improvement of bogs. The value of such land is not sufficiently known or appreciated by gentlemen possessing thousands of acres of such soil, now producing little or nothing, except heath. Many parts of Kerry, Cork, Clare, Waterford, Mayo, Galway, and other counties in Ireland, abound with mountains of this description, which, in their present state, are of very little value; but by cultivation, might be converted into excellent arable land, at no greater expense than the ordinary cost of tilling. Such mountains are peculiarly suited to the growth of timber, especially fir. An example of what such mountain land is capable of producing, under proper management, may be seen at Glanbeh, in the county of Kerry. Some twenty or thirty years ago, the traveller beheld a black and dreary mountain, covered to its lofty summit with heath, and not producing one penny an acre; but under the fostering care of the late Lord Headly, the proprietor, whose loss, as an improving landlord, will be long felt in that part of the country, this district was so much improved and altered in appearance, for the better, that now the mountain scenery and the face of the district generally are considered agreeable and picturesque, forming a strongly marked contrast with what it had been twenty or thirty years ago; and proving the wisdom of land proprietors, who make permanent improvements in their own estates, and encourage their tenantry to do the same, by a liberal allowance for labour and outlay of capital. This district is favourably circumstanced in reference to manure, an inexhaustible quantity of sea-sand being within a very short distance of the base of the mountain.

The waste lands of Ireland possess peculiar advantages, which facilitate their improvement. While the maritime wastes have the convenience of sea-rack and shell-sand, those in the interior, generally speaking, are not far distant from marl, lime-stone, lime-stone gravel, or some other manuring substance calculated to improve their condition. The subsoil frequently answers as a good manure, when well mixed with the surface, and left for some time under the influence of the atmosphere. This fact, though well worth knowing, is known to very few farmers, who, ignorant of the beneficial influence of the subsoil, studiously exclude it altogether from the upper surface. Marl is found, sometimes, under the bog, which answers well as a manure.

Many of the mountains and bogs of Ireland rest on masses of sand-stone, which, in districts far from lime-stone, lime-stone gravel, marl, or shell-sand, would answer as an excellent manure. By grinding the sand-stone in a mill similar to a bone mill, the powder being mixed with the peaty soil, and further manured with dung, would no doubt produce good crops for man and beast. The powdered sand-stone would act upon the peaty soil both mechanically and chemically; the mechanical action being employed to pulverise the soil, while the chemical action tends to promote vegetation. It would be well to mix the powder with a little lime or vegetable earth, if it could be conveniently procured. This mixture would answer well as a top dressing, not only for peaty soils, but for other descriptions of land also. The soft new red sand-stone is the best, being easily ground into powder, and containing perhaps more marl.

In the absence of a better description of manure, the soft or decayed trap rocks would be found, when reduced to powder, to be highly beneficial to mountain and bog lands. The mechanical effect of this powder would be somewhat similar to that of the sand-stone, and being chiefly composed of felspar and hornblende, which are known to contain potash, soda, lime, and other substances favourable to vegetation, we have no doubt it would prove beneficial not only to peaty soils, but to other different kinds of soils also.

In a country abounding with bogs as Ireland, it would be satisfactory to try the effects of these substances, the author never having witnessed the results produced by their application to any kind of soil himself. Since this article relating to the application of powdered rocks to bog soils was written, the author has been informed by the Honorable Mr. Nugent, of Higham Grange, Leicestershire, that he used powdered sand-stone in the improvement of peaty soil, and experienced from it the most beneficial results. He is a gentleman of scientific taste, and great practical skill, as an agriculturist; and there is no doubt that if we were to follow his example in Ireland, in reference to sand-stone powder, we should soon be convinced of its beneficial effect on peaty soils.

Some peaty soils are so impregnated with iron as to be absolutely poisonous to plants. The poisonous influence, however, of the feruginous matter may be neutralised by the application of lime to the soil containing it.

As a direction to those who understand nothing of peaty soils, it may be well to observe, that mountains of moderate slopes, with a surface covering of from one to three feet of black peaty mould, and free from excessive moisture or feruginous matter, are most easily reclaimed. Such slopes, facing the south, are preferable to similar ones of any other aspect; and a northern aspect is the worst of all. A shaking bog, with a great depth of soft, spongy, undecomposed vegetable matter, surcharged with water, and producing but a scanty supply of white light ashes, when burnt, is the most difficult to be reclaimed, and, when reclaimed, is most apt to revert to its original state of peat, and therefore requires most care to keep it in a productive condition. In proportion as a peaty soil approaches these two extreme conditions, so will it be easy or difficult to bring it to, and retain it in, a productive state.

THOROUGH DRAINING.

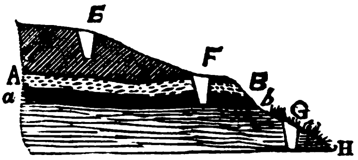
The farmer desirous of reaping a plentiful harvest, must, in the first place, be particularly careful to retain no more water in the soil than is essential to vegetation, a greater quantity being invariably injurious. His land being dry, his next care should be to enrich it with manure, without which an abundant crop cannot be expected. The last duty that devolves on him is to keep his land clean. These three principles must be always kept in view: any one of them being neglected, must prove injurious. Manure is thrown away, to no purpose, upon land (especially in cold climates,) containing an excess of water, which never fails to diminish the fertility of the soil, and encourage the growth of coarse grasses, and useless weeds. When the ground is not kept clean, weeds encroach upon the useful plants, often gaining the ascendancy by extracting from the soil an undue proportion of nourishing juices, which should be reserved solely for the use of the growing vegetable intended for use.

When noxious weeds are allowed to grow up among corn or vegetables of any kind, they deprive the crop of its due proportion of light and air, which are essential to its growth.

The same remarks apply to pasture or meadow land, which should be kept dry, manured, and clean. How often have we seen useless weeds occupying the place of the sweetest herbage, by smothering it altogether. This should be prevented by checking the growth of, or eradicating, such weeds, before their number and size become injurious.

Formerly few persons understood draining upon scientific principles: the plan then pursued was both expensive and inefficient, owing to a want of knowledge of the geological formation of the earth's upper strata. A proper knowledge of the cause producing excessive moisture frequently saves time, labour, and expense; as a single drain, cut in the proper place and direction, may effect more than ten made without reference to the producing cause, as known by the aid of science.

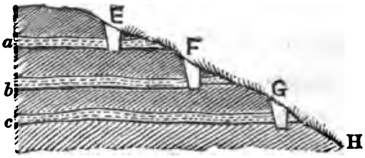
Rain water is retained either on the surface, where it evaporates, or penetrates to a lower level through beds of sand, gravel, or other permeable substances; and at some small distance beneath the surface, meeting an impenetrable bed, it flows through the porous stratum, which usually terminates at, or near, the surface, on the side of a declivity, or at some point lower than the source, and at which point it escapes, spreading itself on the surface, in all directions lower than the point of escape. While the water remains very far under the surface it does no great injury; it is therefore the business of the drainer to check its progress before it reach the surface, by confining it to some channel, from which it may be carried away through some convenient outlet.



The observations we have been making will be easily understood by referring to the annexed diagram, where A B represents the porous stratum through which the water penetrates, escaping at B; *a b* is the tenacious stratum which resists the further descent of the water, and, therefore, the pressure from above will force the water out at B, which will evidently spread over the distance B H. To effect this, it is manifest a drain cut at E would have no effect; to arrest the progress of the water percolating through A B, the drain E should descend below *a b*, which, in all cases, would be expensive, and in many impossible, the distance between E and the stratum *a b* being too great. Having ascertained, by sinking at E, that the stratum AB is too low, a skilful drainer relinquishes the cut at E. It would be equally injudicious to cut a drain at G, as the space B G would still be subject to the drenching influence of the water escaping at B. But by making the cut at F, the spring would evidently be arrested in its course, and therefore could not reach or injure any of the ground between B and H. From this investigation, it follows that the drain ought to be cut a little above the point which separates the wet and dry portions of land, which would dry the entire of the space B H, subject to the injurious influence of the spring issuing from the point B.

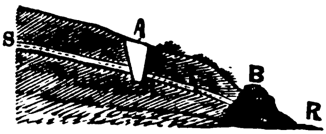
There are cases in which two or more springs issue from the face of the hill, at different points, as may be seen in the annexed diagram.

The drain at E protects the ground between E and H, from the influence of the spring *a*, and the drain at F dries all the space FH, so far as the spring *b* is concerned; but without the drain at G, the space GH would still be under the influence of the spring issuing from the point *c*.

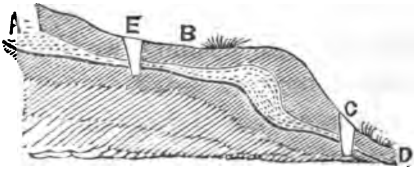


In the second last wood-cut, if the drain at E happened to go below the stratum AB, it is evident that the drain at F was not at all required. But in many cases, it is a matter of extreme difficulty to know whether or not the drain sinks below the stratum through which the spring percolates. Therefore, after having cut the drain E, it would be advisable to wait for some time, in order to ascertain whether the water ceased to issue from the point B, as in the event of its having done so, a drain at F was then unnecessary. A knowledge of this fact is of the utmost importance to the drainer; as without it, numerous drains might be cut, which perhaps might not be as effective as a single one made in the proper place.

It does not unfrequently happen, that a spring ST is interrupted by a rock R, which, combined with the pressure from above, forces the water to the surface, causing a swamp from A to B. When this happens, a drain at A, by taking away the pressure from above, will prevent the water from oozing out between A and B. Such obstruction as is here represented is a case of common occurrence, and to remedy its injurious effects, the drainer must be guided by scientific principles, which are not evident to every common observer. Hence the necessity of a knowledge of science in the practice of draining.



There are various causes which produce swamps, that may be removed by duly considering the circumstances under which they exist. A careful examination of the local stratification will be the best guide in every case; and we may mention, that every particular case requires a peculiar mode of treatment, which must occur to every one acquainted with the general principles of science, without which, endless experiments might be tried, producing no satisfactory results. In difficult cases, the drainer should proceed with great caution, as otherwise considerable time and labour might be expended on a work which should ultimately be abandoned without having produced the desired effect. For instance, should the percolating spring lie too far below the surface, it would be useless labour to attempt to sink a drain to such a depth. Therefore the drainer, before he commences the drain, should dig a pit to a certain depth, by which he shall ascertain whether or not the water is within a reasonable distance of the surface.



There are cases in which a single drain may prevent two or more swamps, as may be seen in this diagram, in which A D represents the spring, the head of which (A) being higher than B, the water is pressed up at B and D, where the swamps are formed. These swamps are prevented by making a cut or drain at E, which will diminish the head pressure, and prevent the water from oozing out at B and CD, rendering the cut at C quite unnecessary. It then appears that the upper drain should be made first, and sufficient time allowed to watch its effect, before another be made lower down, as at C; as a drain at C is quite unnecessary, the one at E being sufficient to prevent the swamp at C, as well as that at B.

In a flat country, which contains a superabundance of surface water, the same degree of scientific skill is not at all required as in an undulating surface.

When the surface is flat, the excess of water on it arises from the slowness of evaporation—the only natural means of getting rid of it: under such circumstances, a number of drains must be made, sufficient in capacity and number to collect or convey away the water, as shall be shown farther on.

What has been said is with a view of pointing out cause and effect, which should be carefully considered by every one who would aspire to eminence in this useful art.

Without a thorough knowledge of the cause of the disease, it is worse than useless to attempt to apply a remedy, which perhaps, instead of curing, might increase the disease. Having laid down some general principles in draining, we shall next proceed with the subject more in detail.

In mountain slopes, springs are in general confined to particular localities, as above described; in which case, a single cut may be sufficient to arrest the injurious effects of the springs. But should there be a general oozing of water through the entire side of the slope or hill, which, indeed, is scarcely ever the case, then such drains as are represented in the preceding cuts would be quite useless, at all events insufficient. If such a case should occur, the drains should all run down the slope, at regular distances from each other, as shall be shown further on, by which a thorough drainage is effected. Though it has been recommended to carry off the superabundant water of springs by means of single cuts, made in certain directions, yet it is not intended to convey the idea that such cuts are sufficient to effect a thorough drainage, without the assistance of frequent or subdrains. And the same observation applies in every case where a single cut is recommended to convey away, and arrest the progress of, a spring. When, however, the great bulk of water supplied by the spring is carried off by a single cut, judiciously made, the thorough drainage will be effected at a less expense, and by fewer subdrains. In Ireland, where the occupiers of land are so poor, a general system of thorough draining is out of the question, unless the landlords lend their assistance. It is, however, in the power of every tenant to prevent his farm from being completely drenched, by making a few drains to carry off the superabundant water issuing from copious springs. This will be doing something, and by employing every spare day in effecting a thorough drainage of his fields, a good deal may be accomplished in a few years. By paying due attention to draining, he might enhance the value of his farm four fold. The landlords should mutually join in deepening the natural outlets, where the drainage of the district required it. They might, also, provide such farming implements as are beyond the means of the great mass of their tenants to procure. Where draining tiles are indispensable, the proprietor of the soil ought to supply them also. The permanent improvement of the soil, being mutually advantageous to both landlord and tenant, they should mutually cooperate to render it as productive as its capabilities would admit. Our land is proverbially fertile, but owing to the dampness of the climate, is charged with too much water; therefore, it is of paramount importance to pay due attention to drainage, by which the holders shall be enabled to pay their rents, and reserve something to be applied to their own personal comforts. We have known an instance of land being let at five shillings an acre, which the tenant was hardly able to pay, from the produce of the ground; but after a thorough drainage was worth thirty shillings, which repaid the tenant for his labour in a very short time, leaving him a good interest in the farm during the unexpired term of his lease.

Clays.—In draining clay soils, the source from which the superabundant moisture proceeds must first be ascertained before any remedy is attempted. If the surface be not horizontal, it obviously indicates the existence of a spring, either in some higher position, or in the field itself; and when the surface is flat and horizontal, the source of the wetness is rain, which falling on such ground, becomes stagnant, than which nothing could be more injurious to it. Clay soil is impervious to, and retentive of, water; and therefore, can never be thoroughly improved till a perfect drainage is effected.

When the wetness proceeds from a spring existing higher up, it may be cut off by a single drain made in the proper direction, so as to intercept it. When the field has little or no declivity, and exhibits a general oozing of water, some, not willing to encounter the expense of a better system, carry off the stagnant water by a judicious form of ridges and furrows, "with small water furrows in the hollows, which cannot be levelled or filled up." This mode of drainage cannot be recommended; the bottom of the furrows is rendered partly useless, on account of being deprived of its due proportion of the soil, and from the pernicious effects of the stagnant water. Besides the unsightly appearance of ridges and furrows, much ground is gained by adopting the plan of under-ground drains.

When a flat clayey field rests on a bed of gravel, stones, or chalk, Mr. Elkington, once a very eminent land-drainer, recommended to bore auger holes, or dig deep wells into the under stratum, through which the water might pass away. In land thus circumstanced, this mode of drainage would be both economical and effectual. The places, however, to which the use of the auger is applicable, are so seldom met with in this country, that its use is scarcely known amongst Irish drainers. This plan, therefore, though once in very great repute, has been superceded by one which is found to be more practically useful.

Loams.—Those lands skirting rivers and streams are generally composed of loam or rich alluvial earth, which is frequently damaged by springs issuing from the adjacent banks, as well as by stagnant water. Such places are drained by making a cut sufficiently deep, along the upper side of the flat, to the next discharging point. The surface drains, communicating with the main one, are to be filled with broken stones to within about eighteen inches of the surface.

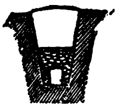
The mode of making the main and secondary drains shall be explained when we come to treat of thorough draining, as practised by Mr. Smith of Deanstown, and others who have distinguished themselves in this particular department of agriculture.

In draining land, it is a matter of some difficulty to ascertain the required capacity of each drain, to carry off the water that may spring from below or fall from above. In the case of springs, it is not so difficult as in the other, because they shew at once what quantity is to be carried away. By measuring the average quantity of water that falls in the locality to be drained, a data may be founded on it, in connection with the fall, from which the exact size may be accurately calculated. A very small drain, with a tolerable fall, is capable of conveying more water than most persons would suppose; the drains, however, "should be made to carry off the greatest quantity that falls, though it occur only once in a lifetime."

Having given directions to drain an extensive tract, by cutting drains in such a manner as would intercept springs, and prevent them from spreading, we shall next proceed to show how each field is to be drained thoroughly.

Some fields may appear so dry as not to require thorough draining, "but in pursuing a proper system of drainage, every field should be thoroughly examined in regard to its state of wetness throughout the year, for that land is in a bad state which is soaking in winter, though it should be burnt up in summer; but the truth is, burning land requires draining as well as soaked land, because drains will supply moisture to burning land in summer, while it will render soaked land dry in winter." This may appear to many as a strange doctrine; experience, however, proves the benefit conferred on every description of soil by thorough draining, therefore we do not mean to question its utility.

Before commencing the ordinary drains, the first thing to be done is to lay out main drains, which should invariably run along the bottom of the principal hollow or valley of the grounds. The ordinary drains should be directed into the main one at right angles. When the farm or field has different inclined planes, each plane must have a separate system of drains for itself, and if, as Mr. Smith says, "any lesser hollows occur in the field, they must also have their proportional mains or leaders." Having determined upon the direction of the main drain, which, of course, should have a sufficient fall to carry off the water, the next thing to be considered is its construction. The main drain should be 3 or 4 feet deep, preserving as uniform a fall as the nature of the ground will permit. When the main drain has to convey away the water of a large area, its size must necessarily be greater than when it has to convey the water of an area of less extent, the declivity in both being equal. Mr. Smith says that "with a fall in no place less than 1 foot in 100 yards, a drain of 10 inches wide, and 12 inches deep, will void the rain water from 100 acres." The sides of the drain should be firmly built with moderate sized stones, and covered on the top with flags. Some recommend to flag the bottom of the drain, which, no doubt, renders them more permanent, but increases the expense, and is by no means necessary, except where the velocity of the water is so rapid as to endanger the stability of the sides—a thing that very seldom occurs. If the expense be no object, flags or sole tiles may be used for the bottom. It is of some importance to have the main drain, as well as the ordinary ones, deep and narrow at the bottom; as when the water-way is narrowed, its increased velocity tends to keep the bottom free from mud, or other deposits, which might choke it up.



Where the farm or fields are crossed by minor hollows, these must be supplied with sub-mains, running along their bottom, 3 or 3½ feet deep, built somewhat similar to the principal main drains, with a suitable passage for the water to be conveyed through them. Where the flow of water is not considerable, a more simple construction would answer the purpose, namely, an inverted couple, such as is represented by number 5. Where stones

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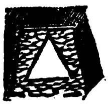


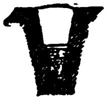
are scarce, a large description of tile will answer the purpose, such as number 6. p. 294. An inverted tile, with another to cover it, will answer the same purpose, and is strongly recommended when the quantity of water demands it. Neither of these, however, should be used, except where stones are difficult to be had. In making ducts of coupling stones, the stones should always form an angle at the bottom, and recede from each other at their upper ends. This is a better form of duct than that formed by two coupling stones, meeting at the top, with their lower ends separated. A main tile of 4 inches wide, and 5 or 6 inches high, will be sufficient to carry off a large quantity of water; but should one of these tiles be considered insufficient, two may be placed side by side, or one over the other. It ought to be remembered, that whether the conduit is formed of flat stones or of tiles, as mentioned above, they should be covered over with small stones, if convenient; if not, gravel will answer the purpose. Every main drain should be 6 inches deeper than those that fall into it.

Cases may occur, where the declivity is so abrupt as to increase the velocity of the water to a degree injurious to the materials of which the main drains are constructed; in such cases, the bottom of the main should be built like steps of stairs, of bricks or flags, which will have the effect of breaking the fall, as is very properly observed in "the book of the farm."

Having laid down the position of the main and sub-main drains, the next thing to be considered is the frequent drains, as they are sometimes called.

When the field to be drained has but one plane of declivity, one main at the bottom will be sufficient, which should, according to Mr. Stephens, never be nearer than 15 feet to the trees growing in the fence, or 9 feet if a mere hedge. When the main drain is too near the fence, the roots of the trees or hedge might choke it up, and be themselves injured. "The old ditch should be occupied by a small drain, and filled up with earth from the head ridge." This, no doubt, is much better than to convert the old ditch into a main drain, but few farmers will go to the trouble or expense of opening a new drain, when the old ditch, so near at hand, and almost ready made, will answer the purpose. The main should never be left open, as the grass and deposits would soon choke it up. When the field has but one plane, all the small drains must be cut parallel to one another, right down the slope, all entering the main at the bottom at right angles. When the field has no fall, the parallel drains must be cut deeper towards the main drain, thus making an artificial fall, which will be sufficient to carry off the water.

When the ground to be drained consists of "stiff strong till, or a dead sandy clay," Mr. Smith recommends that the distance from drain to drain should not exceed from 10 to 15 feet; "if a lighter and more porous subsoil, a distance of from 18 to 24 feet will be close enough; and in very open subsoils, 40 feet distance may be sufficient." Not many years ago, it was the usual practice to run the frequent drains obliquely down the slope, entering the main drain at the bottom at unequal angles; but as the office of these drains is to discharge the water from the ridges, and convey it as quickly as possible into the main drain, it is obvious that they all must be directed at right angles to it, by which they run right down the slope. Therefore, when the ground is composed of more than one inclined plane, it is obvious that all the drains cannot be parallel. The general rule, which will apply in every case, is to run every frequent drain right down the plane in which it is situated. By observing this rule, the water will be conveyed to the main drain in the shortest time possible. But if all the frequent drains of two or more planes of declivity be drawn parallel to one another, some of them must necessarily pass down the slopes obliquely, and therefore cannot discharge the water into the main drain quickly. The frequent drains should be of sufficient depth, so as not to be injured by cattle, or disturbed by deep ploughing. This last operation points out the minimum depth, which should be 2 feet; but the deeper they are the better, provided they have a sufficient drop into the main drain. They should, if practicable, be 6 inches higher than the main, therefore their maximum depth is limited by that of the main drain. Two feet and a half in depth is in most cases sufficient. The width of the drain is not of so much importance as the depth. The bottom may be made so narrow as barely to leave sufficient room for the workmen, say from 3 to 4 inches, and the top may extend to the breadth of from 12 to 14 inches. The bottom should have as uniform a fall as the nature of the ground will admit, and should be filled with broken stones to within 18 inches of the top, as in the annexed cut. The stones should be broken to the size of 2½ inches in diameter. Sometimes straw and furze are used instead of tiles or stones,



which never answer well: these, as well as coupled drains, are objectionable, as they encourage rats and other vermin to take shelter in them. After having filled the drain, to within 18 inches of the surface, with broken stones, or small stones gathered from the adjacent fields, the upper surface of the stones should be covered with a thin turf, or scraw, as it is called, cut in some convenient place, or with peat moss, when convenient (see page 292.) This covering will form a sort of crust, which should never be disturbed by even the deepest ploughing. This covering will prevent mud or sand to choke up the drain from above, the water being constrained to enter pure from the sides. It is best to complete the cutting of the drain before any part of it is filled with broken stones; because any fault in the construction can be easily detected, but which might pass unnoticed if filled as the drain proceeded. It ought to be recollected to fill from the higher level downwards, as when a drain is filled from a lower level upwards, any clay falling from the sides during the construction would lodge among the broken stones, and choke the passage. When the sides of the drain have a tendency to fall in, it must be supplied with the broken stones as the work proceeds, as otherwise the drain might become disfigured. The drainage may be best executed when the field is in grass.

In every case of thorough draining, a small drain should connect the top of the frequent drain, at the upper end of the field, which will have the effect of drying the upper head ridge, and also of protecting the ends of the ridges from the fence-ditch. When the frequent drains are very long, it is recommended by some, to run a sub-main drain right across them, in the middle of the field, lest they should burst, from being overcharged with water; but by making them of suitable capacity, no such danger need be apprehended, and therefore their use may be dispensed with. In the absence of a proper instrument, the fall of the drain is ascertained by the direction of the water in the bottom of the drain; but when the drain is dry, a bucket of water thrown on the bottom, after having been cleared out, will at once indicate the fall. Mr. Smith mentions that a fall of four inches in a mile will be sufficient to carry off the water.

When tiles are used, the drains need not be so deep as when filled with broken stones. The figure in the margin represents a drain with a tile, through which the water passes. In England and Scotland, draining tiles are very common, and a source of considerable profit to the manufacturer; but in Ireland not a single tile is manufactured, that we are aware of, except at the Earl of Courtown's, near Gorey, in the county of Wexford. Many parts of Ireland are supplied with clay fit for making not only draining tiles, but fire bricks, and coarse ware of every description. Now that draining is becoming more general in Ireland, a good demand may be had for tiles, which, if manufactured in districts where stones are scarce, would pay well. In the absence of flags or stones, or where the expense of procuring tiles is beyond the reach of the occupier, the surface sod should be inverted, and laid on the shoulders prepared to receive it, as represented by the cut in page 272, leaving sufficient room beneath for the water to pass away. This will answer very well for

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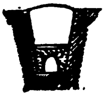

many years; but when the sods sink to the bottom of the drain, and choke it up, the process must be repeated, by removing the obstruction, or making a new drain. The failure of the old drain is generally indicated by the water which comes to the surface, in the vicinity of the deranged part of the drain: such drains are very common in many parts of the county of Limerick, especially in the small county.

In draining land, it is always necessary to ascertain the direction of the slope or fall of the ground, which can always be determined by means of the levelling instrument described in the preceding part of this work; but as the price of this instrument is beyond the reach of many practical drainers, and its use known to but very few of that class, a cheap and simple level may be obtained of any of the Dublin opticians, which will be found to answer all the purposes of the practical drainer, whose principal object is to ascertain the direction of the fall, and not its amount. The instrument, which is furnished with a bubble, is placed on the top of a four-legged stool, and levelled by raising or depressing the end or side of the little stool or table, till the bubble be made to stand in the middle of it. The instrument being levelled, a person with a staff is sent in different directions, and holding it at different points, in a perpendicular position, the man at the instrument viewing it along the upper surface of the little table, at once discovers the direction of the fall, which is indicated by the visual ray cutting the staff at a higher point. When the visual ray cuts the staff at a lower point, viewing it along the upper surface of the table, there is a rise in the ground from the table in the direction of the staff.

In the case where whins or similar materials are used as ducts, they should invariably be covered with scraws or peat moss, well pressed, in order to prevent the water from entering at the top of the drain, which, no doubt, would carry with it particles of sand or clay, that would ultimately choke up the drain, and prevent the free passage of the water through it. When the water enters the drain by the sides, it is deprived of any sedimentary matter in its descent from the surface, through the fissures or cracks which must necessarily take place in the substratum, after the drainage has been effected.

When the slope or inclination of a drain, only of sufficient capacity to void the water, diminishes, the velocity of the water necessarily diminishes also. And as the transverse section of the drain varies inversely as the velocity of the water passing through it, it follows that where the inclination of the drain diminishes, the breadth must increase so as to be inversely as the velocity of the water; and on the contrary, where the drain becomes more precipitous, the breadth may be diminished, so as to make the cross-section still inversely as the velocity of the water passing through the drain. This is only intended to apply to cases where the quantity of water is considerable, and the drains apt to be completely full. When the quantity of water is small, and the drain not likely to be, at any time, entirely full, then it may be made of uniform breadth throughout, no fear being apprehended of its blowing up.

The plough is sometimes employed, with good effect, in making the frequent drains, which require, however, to be dressed up with the spade, as no application of the plough could finish the sides.

The scientific agriculturist will not allow the water, collected by his drains, to escape from his farm without turning it to some account. In most farms, it may be employed in irrigating some parts of them, which would have a beneficial effect, as shall be shewn further on, in the article on irrigation.

Wherever the scale is not represented, the cuts are not laid down to any particular scale.

SUBSOIL PLOUGHING OR DIGGING.

A thorough drainage having been completed, its effects upon the subsoil will soon become visible. The excessive moisture in the vicinity of the drains being drawn away, the subsoil begins to crack in those parts, owing to the contraction which necessarily takes place in it as it begins to dry. The water at greater distances from the drain will find its way into them through these cracks or fissures; and then the process of drying goes on till the entire of the water contained in the soil shall have escaped. It is manifest, from what must necessarily take place in the subsoil subsequent to the removal of the water, that the rain falling on the surface must soon find its way down through the fissures of the subsoil, from which it escapes into the drains, as before, and through which it is ultimately conveyed to the natural discharging channel of the district. The underground operations of nature, thus described, may be witnessed on the surface, in clayey or peaty soils, which absorb and retain three times as much water as some sandy soils do. In spring, when such clayey or peaty soils become dry, they shrink in considerably, separating into hard masses, with large fissures [illegible] on this principle, the degree of contraction, diminution in bulk, and hardness in every soil, will be in proportion to the quantity of these it contains; and as most subsoils partake more or less of either of these, it follows, that draining has the effect of producing these masses of different degrees of hardness in every subsoil, except those that are sandy or gravelly. The tender roots of the growing crop cannot enter these solid masses, which also exclude the air: in dry weather, the active soil over them will be parched, and in wet weather, the rain, with all the nourishing substances it brings from the atmosphere, passes quickly through the thin stratum of active soil, and descends through the fissures, where the beneficial effects of all are partly lost. The best part of the artificial manures is also washed down through the fissures, where its beneficial influence is lost. Hence, it is evident that something more is required than thorough draining, in order to preserve to the growing crop all the nourishing qualities of the soil, atmosphere, and artificial manures. To attain this desirable object, subsoil ploughing has been found eminently successful.

The process of subsoil ploughing is very simple. A common plough, drawn by two horses, goes before the subsoil plough, removing a strip of the active soil, and laying it to one side; the subsoil plough follows in the open furrow, penetrating through and breaking the subsoil, without removing it to the right or left. The common plough again throws another strip of the active soil over the subsoiled furrows, the subsoil plough following, as before, softening and breaking up the subsoil to such a depth as may be thought necessary. In this manner the process goes on till the entire field is gone over. By this process the active soil is left on the top, and the subsoil only stirred up and broken, none of it being yet mixed with the active soil.

The stones brought to the surface by the subsoil plough are thrown on the ploughed part, to be used afterwards in some other field to fill up new drains. Should the subsoil ploughman meet with stones so deep and fast in the ground as not to be removeable by the plough, they must afterwards be picked or perhaps blasted, their site being marked by a wooden peg stuck in the ground. This last part of the labour, and that of throwing the loose stones on the surface of the ploughed ground, is done by a little boy who attends the subsoil ploughman. These furrows should run at right angles to the drains, in order to allow the water falling on the surface to pass more freely into them. Mr. Smith of Deanstown, who may be said to be the author of this plan, recommends to go to the depth of 16 inches, leaving two inches over the crown of the frequent drain undisturbed. He very properly recommends not to apply the subsoil plough till one year, at least, after the thorough drainage has been effected.

The subsoil plough is very strong, and of a particular construction, requiring four, and sometimes, in strong and stiff ground, six horses. This process requiring so many horses, it cannot be practised to any extent among Irish farmers; but where spade labour is so abundant and cheap as it is in Ireland, the use of the subsoil plough may be altogether dispensed with.

After having the subsoil broken up, either by the subsoil plough or spade, two or more inches of it may be mixed with the active soil, at every subsequent ploughing or digging. When the subsoils are rich, Mr. Smith recommends "to plough to the whole depth of the moved soil on the first application of the trench plough." Mr. Smith says that "when land has been thoroughly drained, deep wrought, and well manured, the most unpromising sterile soil becomes a deep rich loam; rivalling in fertility the best natural land in the country." Though, from want of capital, it is hopeless to expect to see Mr. Smith's plan of cultivation carried out to the extent that would be desirable; yet, under the fostering care of an encouraging landlord, a great deal may be done by the substitution of manual for horse labour; and though the business may not be done so quickly by the spade as by the plough, it will be better done. Sir James Murray, who has long directed his attention to the improvement of agricultural chemistry, says, "our damp clay land is not half moulded, broken, or pulverized; we trust too much to horse labour, and too little to manual." In another part of his pamphlet, entitled the "Fertilizer," he very truly observes, "at a time when half our poor are unemployed—when we have scarcely any manufactories but land, and in a country where land was not considered a manufactory at all, it is our sacred duty to open new sources of work for our people, and to make them producers rather than consumers." This is a sentiment in which all parties in Ireland must concur. Numerous plans have been proposed, from time to time, to improve the condition of Ireland; but among the various plans devised for her moral and physical improvement, nothing is so peculiarly calculated to effect those desirable objects as to pay due attention to the reclamation of her bogs, and other waste land, and also to the improvement of her soil generally by draining, deep working, a proper rotation of white and green cropping, and house-feeding. This would give employment to the people, by which they would feed themselves, and remunerate their employers.

The following passage from a letter written by Mr. Blacker to the chairman of the Tuam agricultural society, will show the importance of draining:

"I have just been making a comparison of the crop of potatoes in the same field, part on ground thorough drained, and the other part not; and the difference was three tons per English acre, and it would have been half more, if the drained ground had been planted in drills, which ought always to be the case, when the land is drained. The best thing your man can do is to persuade each tenant to make this improvement, and drain as it ought to be, one-fourth, one-third, or one-half of any field, and then measure or weigh the crop in each. I think the first crop of potatoes will pay the whole cost of the land that has been in much want of it."

These improved modes are beginning to be partially practised in Ireland, and when the benefits resulting from them are better known, there is no doubt they will become general. The beneficial effects of draining have been long known and appreciated; but deep ploughing is comparatively of modern date in husbandry. When there is an excess of moisture in the soil, the heat of the sun, which is intended to warm it, and thereby accelerate the growth of the plants, is expended in evaporating the water from the surface. This excess of moisture, besides keeping the soil cold, dilutes too much the food intended for the plants, prevents a sufficiently rapid decomposition of the vegetable matter in the soil to take place, and generally produces acid compounds, which, when imbibed by the plants, must prove more or less injurious to them. The sun's rays being constantly employed, during the day, in drawing the excessive moisture upwards from the soil, the air is prevented from entering it downwards, and diffusing its beneficial influences among the plants. We might point out a variety of cases, in which the presence of too much water in the soil, exercises a baneful influence on the plants; therefore draining becomes absolutely necessary. But draining alone will not be sufficient; subsoil ploughing or digging is an operation that must be gone through, before the soil can be brought to that state which is most conducive to the rapid and healthy growth of plants.

By breaking up the subsoil, after the drainage has been effected, any water that may have remained in the stiff clay between the fissures will be set free, and will easily make its way to the drains.

The soil being rendered more mellow and porous, will allow a free circulation of air to take place in every direction through it, spreading its salutary influence among the roots, which can now shoot with ease, and without interruption, in every direction.

Having broken up the subsoil, it becomes of importance to deep plough or dig the ground at every subsequent operation, by which new earth is brought to the surface, a deeper soil formed, and its character renovated, and altered both physically and chemically.

By deep working, and carefully mixing the soils, those manuring substances, which, by their gravity, sink, from time to time, too deep into the soil, are brought to the surface, where they communicate to the plants their fertilizing influence. When spade labour is cheap and abundant, nothing is better adapted to the thorough working of the soil. The spade breaks, crumbles, and mixes the soil better than the plough, by which more abundant crops are invariably produced, when the work is done well and with care.

It might appear strange, that a branch of human industry, coeval with the world, and upon which the very existence of the human race may be said at all times to depend, should not have been brought to its ne plus ultra of perfection many ages before this. In all ages since the creation, man has been incessantly employed in tilling the ground, with a view to raise from it the necessary food for his support; and in proportion to the increase of population, and consequent scarcity of land, it became his duty to raise from a given extent the greatest quantity of useful produce, without permanent injury to the soil. In some of the nations of antiquity, a scarcity of the necessaries of life was often experienced, arising from various causes, which, of course, imposed on them the necessity of increased exertion, both of skill and labour, as regarded agriculture. It has, however, been reserved for modern science to effect an improvement in that art, which our forefathers could not have contemplated. They have transmitted to us their practical experience, to which we have added the numerous facts collected from the sciences of geology and chemistry, which are comparatively of modern date. Our forefathers, no doubt, from repeated trials, were aware of many of the obvious qualities of the soil, favourable to vegetation, but were totally unacquainted with numerous others, which lie dormant until awakened into activity by the application of proper stimulants pointed out by science. The science of geology facilitates the labours of the agriculturalist, by pointing out the origin of soils, the cause of their diversity, their general character, the benefit or injury resulting from their admixture, the changes which are constantly taking place on the surface of the earth, arising from mechanical and chemical causes, and a vast quantity of other information, which but that science alone can impart. The science of chemistry enables him to ascertain the element of which all organized substances are composed; the different proportions in which these elements enter into the composition of each particular substance; to analyze the various soils, with a view to ascertain the quantity of suitable food afforded by each for the nourishment of plants, and supply the deficiency, if found to exist, by the admixture of the required substances; in short, the science of chemistry enables him to find out the wants and diseases of his crops, and points out the proper remedy, by the application of proper manures in adequate quantities. By the aids afforded by the sciences of geology and agricultural chemistry, the scientific farmer is conducted to results which he never could have arrived at by any other means; and the perfection of his art, which is still in want of further improvement, is only attainable by combining with practical experience the assistance afforded by science. It could not, however, be expected, that every farmer could be a geologist and chemist; but the outlines of these sciences ought, doubtless, to form a part of the system of education adopted in every school, and especially in schools set apart for the education of the higher and middling class, by which a taste would soon be excited among enlightened farmers, the advantage of which would at once be felt and appreciated. It would, for instance, require but a short time, and a small amount of intellectual exertion, to learn the names of the common rocks of the country, which, so far as the farmer is concerned, are very few in number. He might be told that the loose soil which, in general, forms the surface of the globe, has been derived from those rocks; and that the soil is fruitful or sterile according to the particular rock from which it had its origin. The intelligent farmer could soon learn the general outlines of this science, by which he could see its direct bearing on practical agriculture. For instance, he would find it useful to know the constancy in the relative position and character of the stratified rocks, the general character of the soils upon them, and the cause of the diversity of soils. He would find it equally useful to know the qualities of the soils divided from the unstratified rocks, such as the granite and trap rocks; also the physical characters of the transported sands, gravels, and clays, and the relation between the nature of the soil and the kind of plants that naturally grow upon it.

The effect of temperature on the growth of plants is a fact with which the practical farmer ought to be acquainted. Altitude, climate, and other local circumstances exercise an influence, affecting the vegetation of every country, which is perhaps more obvious to the senses than any other cause, and which therefore ought to form an item of the practical farmer's knowledge. The chemical constitution of the soil and growing crops, is a subject that may require a man's whole life-time to learn, but a great deal of what would prove highly useful in after life may be learned at school in a few months. The agriculturist ought to know that the growing crops, and soil in which they grow, are composed of certain organic and inorganic substances. That the substances which contribute to the growth, nourishment, and support of his crops, are received from the soil and atmosphere. That different plants take in these nourishing substances in different proportions, and are supplied by different soils in different proportions. And though every farmer could not be expected to be able to make a chemical analysis of every soil and crop, with a view to ascertain the exact proportions in which the different substances enter into the composition of each plant, and the quantity present in each soil; yet by learning a little of the outlines of the science, he will be enabled to perform many experiments at the expense of a few pence, which cannot fail of being highly useful and interesting. For instance, "if a handful of soil be infused in a pint of rain-water, and filtered, an infusion of red cabbage leaves will shew acidity, by the red colour produced; on the contrary, if the liquor turn green, the soil is alkaline. If a watery mixture of soil effervesce or bubble up, when vinegar is added it shews that it contains chalk, calcareous matter, or magnesian earth or limestone. Litmus paper can be readily obtained at the chemists', to test soils, when mixed in water. It will point, by the red colour, if the soil be acid: if alkaline, the litmus retains its blue tint."

Knowing when acids or alkalies are in the soil in too great abundance, the scientific agriculturist will at once know the proper remedy to be applied, in order to neutralize the injurious effects of the prevailing substance. Knowing also that the soil is deficient in some of those substances which are required to feed his plants, he will supply the deficiency by the addition of proper manures, in sufficient quantities. By founding his practice on this principle, he will be the less liable to fail in any new experiment he may make to increase the produce of his land; he will also be surer to succeed, under varied circumstances, as regards soils and climate.

A farmer may be very successful in one locality, from long acquaintance with the habits of the soil and climate, and be totally at a loss how to proceed when both are different. Indeed similar soils, in two different climates, may require different treatment; and he who is guided by principle, will not hesitate to alter his mode of treatment according as the circumstances of the case may require, while the person whose only guide is habit, cannot see why he should adopt a different mode from that which he always found to answer. This person, who may be termed a local agriculturist, will doubtless be disappointed, while that man whose practice is founded upon principle, combined with experience, of course, will be sure to succeed, being what may be termed an universal agriculturist. He who knows a little of the geological arrangement of the external crust of the earth, and of the chemical constitution of the different soils, will not find much difficulty [illegible] are com- [illegible] substances. [illegible] the growth [illegible] are received [illegible] different plants [illegible] in different propor- [illegible] in different [illegible] could not be expected [illegible] analysis of every soil [illegible] ascertain the exact proportions in which the different substances enter into the composition of each plant and the quantity present in each soil; yet by learning a little of the outlines of the science, he will be enabled to perform many experiments at the expense of a few pence, which cannot fail of being highly useful and interesting. For instance, "if a handful of soil be infused in a pint of rain-water and filtered, an infusion of red cabbage leaves will she acidity, by the red colour produced; on the contrary, the liquor turn green, the soil is alkaline. If a wat mixture of soil effervesc or bubble up, when vineg added it shews that [illegible] ains chalk, calcareous m or magnesian ea [illegible] limestone. Litmus paper be readily obtain [illegible] the chemists', to test soils, wh

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by some scientific farmers, that the practice is never omitted at the proper season, while others seem to be indifferent to so cheap and available a source of improvement.

In Ireland, which is most favourably circumstanced as regards water and the sinuosities of the surface, irrigation is almost totally neglected, either from ignorance of its beneficial influence as a fertilizing agent, or from a disinclination, on the part of the farmers, to try a new experiment, being satisfied to tread in the footsteps of their fathers, who, no doubt, were altogether unacquainted with the principles and practice of irrigation. The unwillingness of agriculturists to go out of the beaten path, by trying experiments, the result of which they consider doubtful, is a great obstacle to the advancement of local agriculture; "and without actual example before them, neither proprietors nor tenants, except in a few instances, will abandon their previous system."

No land should be irrigated in summer or autumn, these being the seasons when the surface is covered with grass. The proper time for irrigating land, is when the grass is scanty, and its further growth checked by the inertness or inclemency of the season. The operation should therefore be conducted from the end of October to the beginning of April. The general plan of irrigating land is well described in the Irish Farmer's Magazine, in the following terms:—

"A stream is diverted from its course, when descending from higher ground, and carried in a level course along the brow of the hill intended to be watered; similar carriers or levels are formed parallel to the upper one, at intervals down the declivity, and the water being admitted, flows over the brim of the highest level, and passing through the grass in a stream half an inch or more in depth, is received into the next level, which it overflows, and is caught in a third, and so on. It is finally carried off by a stream in the lowest part of the ground.

" This is called catch-work irrigation, and is not only easily formed, but as the water can be completely drawn off whenever it is wished, by causing it to descend by its proper channel, the grass is less liable to become coarse than in meadows on comparatively level land. In the latter cases, namely, in districts comparatively level, a weir or dam is formed across the stream or river, and the water being by this means raised, the whole or a portion of it is carried in a main leader along the highest part of the ground to be watered ; from this leader it is distributed over the surface in secondary leaders or feeders, and open drains being formed in the lowest part of the ground, receive and carry it off to some rivulet. In some places the ground is prepared at great expense, in order that it may receive the water with the greatest advantage ; with this view, the surface sod, if it be pasture, is pared off with the breast plough, and the sods being laid aside, the ground is thrown into ridges of about forty feet broad, and about eighteen inches higher in the centre than at the sides ; a drain or channel is formed on the crown of the ridge, after which the sods are laid on and made firm by rolling ; the water is then admitted by a main leader which is carried along the highest part of the field, from which it passes into the channels on the summits of the ridges, and sods being placed in these channels, at intervals of a perch or thereabouts, the water is made to flow over the ridge, and being caught by a drain in the furrow, is carried off. The channels on the crowns of the ridges become narrower as they recede from the main leader; and this also gives a tendency to overflow.

"Should the land be naturally moist, it is absolutely necessary that it be effectually drained previously to having water brought upon it, as the success of the art depends entirely on the power of rendering the land quite dry at certain times, particularly in summer, thereby extirpating aquatic or marsh plants, and encouraging the finer grasses."

When the after-grass is eaten off, all the ditches and drains should be cleared of weeds, grass, and mud, which should be used to make the surface even, and ready to receive the first flood that may happen in the month of November, or the latter end of October. It is recommended to make the duration of watering at this season about three weeks, with a dry interval of one or two days, making the works after that as dry as possible.

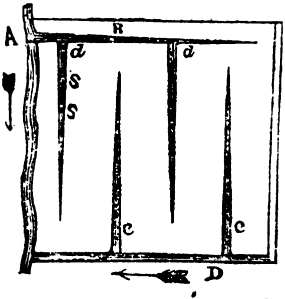
In the months of December and January, the grass should be protected from the effects of the frost at night, by covering it with water, which, however, should be taken off every fortnight during the winter, to prevent the grass from rotting. The best time for taking off the water is in the morning of a dry day.

It would be well to water the meadow again in the month of February, taking care, however, not to leave it on but for a short time. The Rev. J. T. Hamilton says, "that some meadows that will bear the water three weeks in October, November, or December, will perhaps not bear it a week in February or March, and sometimes scarcely two days in April or May."

"In the month of February, two watering of five or seven days each, should be given; and in March, three of three or five days each, according to the [illegible]e of the air, ever suffering the water to remain on longer in cold than in warm weather."

The following diagrams will explain what we have been saying:

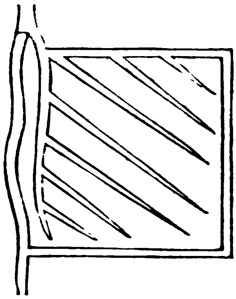
In the diagram, A represents the dam or weir which diverts the water from its course, B the main conductor. At right angles to the main conductor, are laid off the feeders *d d*, which consist of small trenches, about 4 or 5 inches in depth, and about 16 inches wide where they issue from the main conductor, but gradually diminishing as they recede from it, till they terminate in a point. There are other drains *c c*, similar to the former, whose office is at once understood by inspecting the figure. When the water has glided over the surface of the field, it descends to the main drain D, through which it is conveyed back to the river in the direction of the arrow. This main drain very often discharges the office of main conductor to another field lower down, by cutting small feeders at right angles to it; the water being ultimately collected in the bottom drain, through which it is conveyed back to the river. In this manner, the same water is employed to irrigate several fields in succession; which, when the supply of water is scanty, is to be particularly



attended to. In order to make the water flow over all the surface, as it descends through the several feeders, stops, such as may be seen at *s s*, are placed at such distances as are considered necessary to distribute the water equally over the entire surface.

When the slope of the ground is considerable, the small feeders *c c* are useless, as they can never convey the water back from the bottom drain. But when the surface of the ground is level, the water is conveyed in both directions by the double sets of feeders.

When the inclination of the surface becomes considerable, the feeders are to be carried obliquely, but not directly down the slope, as is represented in this figure, when the feeders are supplied, as before, from the main conductor.



If the feeders were to be made directly downwards, the water would flow through them too rapidly, by which the roots of the grass might be denuded and much injured. But by cutting the feeders obliquely across the slope, the velocity of the water is reduced, and the injury which it might in the former case produce is prevented. This species of irrigation is termed catch work.

Parts of the same meadow are frequently flat, while other parts are considerably inclined. When such a diversity of surface presents itself, a scientific irrigator will find no difficulty in applying the process explained in the preceding cases, which in such circumstances might be so combined as to be mutually advantageous.

The irrigation of a diversified surface requires considerable skill in laying out the main drains and feeders to the best advantage which such a surface admits of. An equable velocity should be given to the water if possible, and an equal quantity should flow over all the parts of the ground.

In mountainous and hilly countries, where the streams and rivulets are usually precipitous, the meadows and slopes may be very easily irrigated; as the water may be conducted to the surface, and drawn away from it quickly, at a small expense, and with very little trouble. The water should never be allowed to diffuse itself over any surface from which it cannot be drawn off at pleasure; as when it remains too long on the ground, and becomes stagnant, it proves highly injurious, by disposing the land to produce aquatics, and check the growth of sweet herbage; but wherever the water may be conducted and drawn off at pleasure, without much expense or loss of time, it should never be neglected, as in some localities well circumstanced for the drainer, the value of property, by the process of irrigation, might be considerably enhanced, it being a generally received opinion, "that the elementary food of plants is contained in a state of solution in water, and that no plant can exist without a supply of it, in a greater or lesser degree, in a dense or rarified state."

Without a sufficient quantity of moisture, the roots of grass become withered, and perish; and when they are too deeply and too long submerged, their existence (except aquatics) ceases inevitably. A moderate quantity of water on the surface, moving

quickly, but not with such a velocity as would tear
the roots, is invariably favourable to the luxuri
growth of grass, a result not very easily accounted f
Some naturalists suppose that the water, in its cour
bears with it nutritious food, which it deposits amo
the roots of the grass, and which they say is the s
cause of luxuriance, while others maintain that pu
water, destitute of sedimentary matter, is by far mo
beneficial. Pure water flowing freely over the surfa
answers the temporary purpose of irrigation, whe
nothing is sought but the growth of grass; but we a
persuaded that deposits of decomposed animal an
vegetable matter confer on the land much more lasting benefits. The quantity deposited, however, must be limited, as too much, at once, would have the effect of checking, rather than encouraging, the growth of grass.

Pure water then produces the desired effect quickly, which, however, does not continue for any time; while water containing fertilizing deposits, produces the desired effect slowly, but permanently. We have had frequent opportunities of witnessing these different effects produced, under the different circumstances above stated.

THE END.

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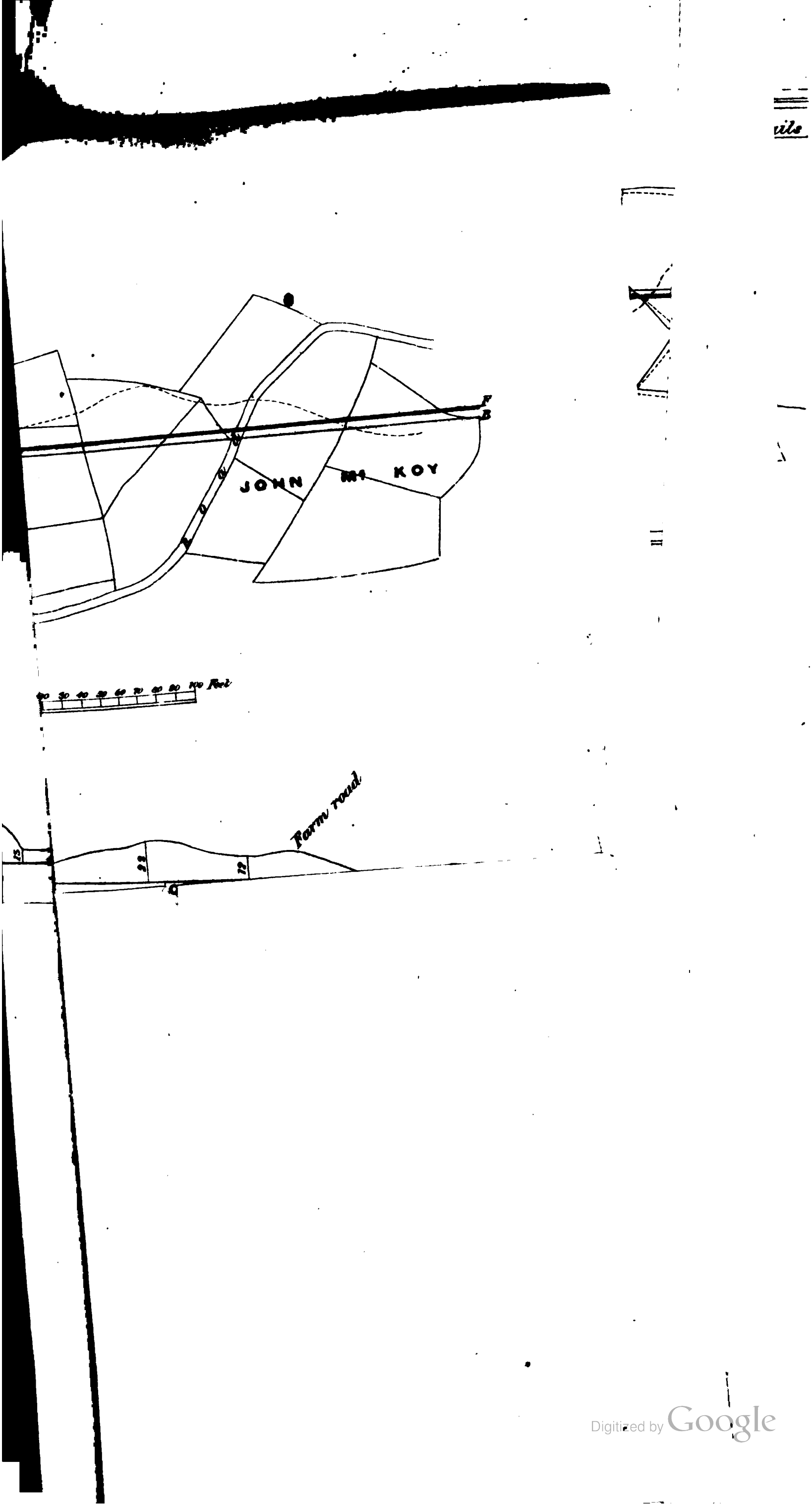
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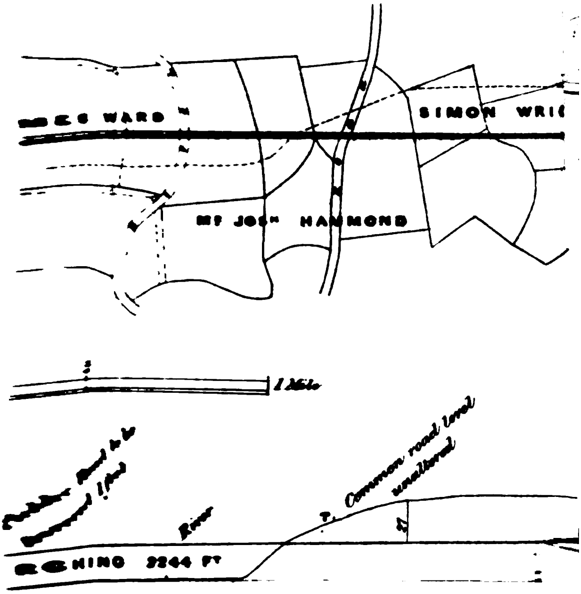

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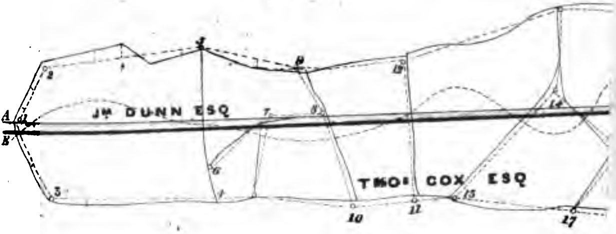
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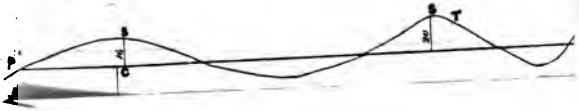
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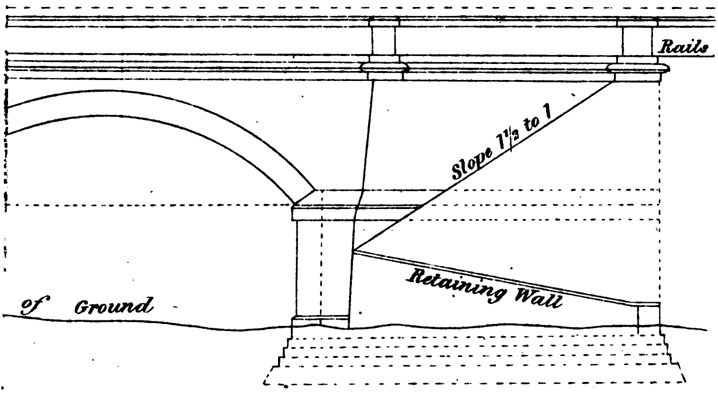
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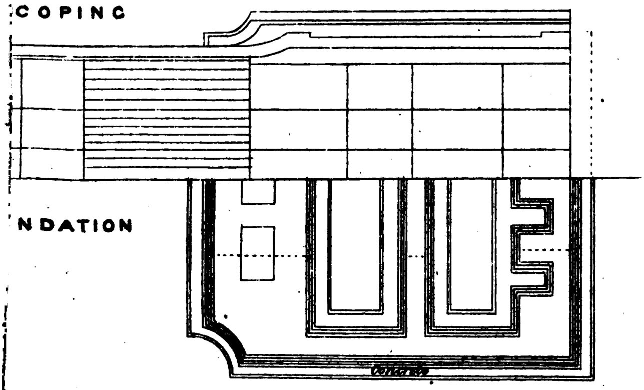
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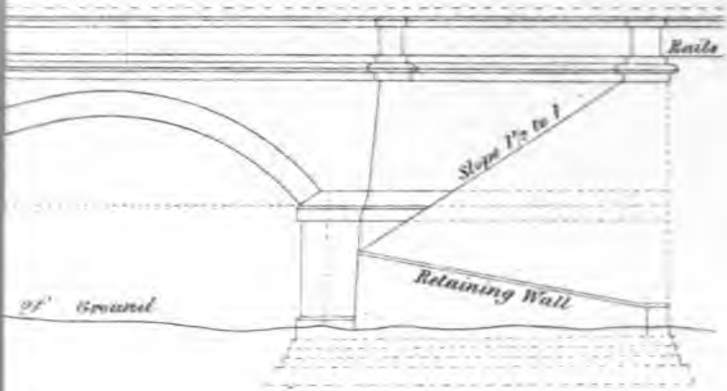
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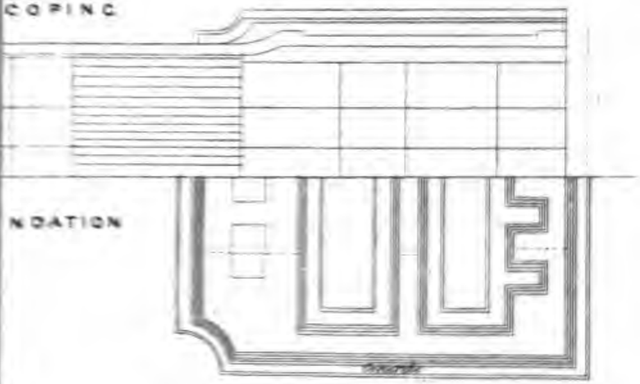
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